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PHOTOVOLTAICS PROJECT

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- Knott's Berry Farm
- Pacific Park
- City of Santa Monica, California
- Alamos Intermediate School
- Glenmeade Elementary School
- University of California, Irvine
- Boys Republic.

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- Siemens Solar
- Trace Technologies
- Omnion
- Campbell Scientific
- Solarex
- Ascension Technology.

Table of Contents

Section	Page
PREFACE	10
EXECUTIVE SUMMARY	1
ABSTRACT.....	5
1.0 INTRODUCTION	7
1.1 Project Purpose	7
1.2 Project Objectives	8
1.3 Purpose and Organization of This Report.....	8
2.0 PROJECT APPROACH	9
2.1 Design Philosophy	9
2.2 Design Specification.....	9
2.3 Acceptance Test Procedures	9
2.4 Data Acquisition Methodology.....	10
2.5 Site and System Selection Considerations	10
3.0 SITE APPLICATIONS	11
3.1 Grid Support – Transmission and Distribution System Deferral	11
3.1.1 Monterey Hills Elementary School	12
3.1.2 Huntington Library	13
3.2 Standardized Design Packages	15
3.2.1 Elizabeth Court	15
3.2.2 Standard Residential Patio Cover System	17
3.2.3 Standard Residential Garage-Mount System	19
3.2.4 Straw Bale House.....	20
3.3 High-Impact, Public Visibility Sites	22
3.3.1 Knott’s Berry Farm	23
3.3.2 Pacific Park, Santa Monica Pier.....	24
3.4 Educational Settings	26
3.4.1 Glenmeade Elementary School	26
3.4.2 University of California, Irvine	28
3.4.3 Alamitos Intermediate School.....	30
3.4.4 Boys Republic	31
4.0 LESSONS LEARNED.....	35
4.1 Marketing Lessons Learned.....	35
4.1.1 Subsidy Continuation.....	35
4.1.2 Commercialization Potential	35
4.1.3 Benefit to California.....	35
4.1.4 User Friendliness	35
4.1.5 Promotion and Educational Issues	36
4.2 Design Lessons Learned	36
4.2.1 Site Selection Criteria	36

4.2.2	Standardization	36
4.2.3	Integration	37
4.2.4	Interconnection Standards.....	37
4.3	Hardware Issues.....	37
4.3.1	Trace SW5548 Inverter Capacity Issue.....	37
4.3.2	Omnion Inverter Coolant Leak	38
4.3.3	Voltage Spike Protection – Omnion Series 2400.....	38
4.4	Operational Lessons Learned.....	38
4.4.1	Economic Analysis	38
4.4.2	Energy Produced During Reporting Period.....	38
4.4.2.1	Value of Energy Produced to System Owners	39
4.4.3	Environmental Benefit	39
4.4.3.1	Net Pollutant Offset.....	39
4.4.3.2	Value of Pollution Offset	39
5.0	CONCLUSIONS.....	41
5.1	Purpose of the Project.....	41
5.2	Project Objectives	41
5.3	Project Outcomes.....	41
5.4	Project Conclusions	42

Appendix I Site Power Production Data Summary Reports for 12 Systems.

List of Figures

Figure	Page
Figure 1. Monterey Hills Elementary School.....	12
Figure 2. Monterey Hills Elementary School Energy Profile.....	13
Figure 3. Huntington Library PV System.....	14
Figure 4. Huntington Library PV System Energy Profile	15
Figure 5. Elizabeth Court Rooftop PV System.....	16
Figure 6. Elizabeth Court Rooftop PV System Energy Profile	17
Figure 7. Residential Patio Cover System.....	17
Figure 8. Residential Patio Cover System Energy Profile	18
Figure 9. Standard Residential Flat Roof Garage Mount System.....	19
Figure 10. Standard Residential Flat Roof Garage Mount System Energy Profile	20
Figure 11. California Polytechnic Straw Bale House Shingle System	21
Figure 12. Cal Polytechnic Straw Bale House Shingle System Energy Profile.....	22
Figure 13. Knott's Berry Farm Company Store.....	23
Figure 14. Knott's Berry Farm Company Store Energy Profile	24
Figure 15. Santa Monica Pier Full Site	25
Figure 16. Santa Monica Pier PV System Energy Profile	26
Figure 17. Glenmeade Elementary School.....	27
Figure 18. Glenmeade Elementary Roof Panel System	28
Figure 19. University of California, Irvine Solar Deck	29
Figure 20. University of California, Irvine Solar Deck Energy Profile	30
Figure 21. Alamitos Intermediate Covered Lunch Shelter	30
Figure 22. Alamitos Intermediate School Covered Lunch Shelter Energy Profile	31
Figure 23. Boys Republic Roof-Mounted System.....	32
Figure 24. Boys Republic Roof-Mounted System Energy Profile.....	33

List of Tables

Table	Page
Table 1. Project Cost Share Distribution	4
Table 2. Monterey Hills Elementary School System Description.....	13
Table 3. Huntington Library System Description	14
Table 4. Elizabeth Court Rooftop System Description	16
Table 5. Residential Patio Cover System Description.....	18
Table 6. Flat Panel Garage-Mount System Description.....	19
Table 7. Cal Polytechnic Straw Bale House System Description.....	21
Table 8. Knott's Berry Farm (Company Store) System Description	23
Table 9. Santa Monica Pier System Description	25
Table 10. Glenmeade Elementary School System Description	27
Table 11. UC Irvine Integrated Materials Solar Deck System Description	29
Table 12. Alamos Intermediate School System Description.....	31
Table 13. Boys Republic System Description	32
Table 14. Energy Value to Owners	39

Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliability energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to \$62 million through the Year 2001 to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research.

In 1998, the Commission awarded approximately \$17 million to 39 separate transition RD&D projects covering the five PIER subject areas. These projects were selected to preserve the benefits of the most promising ongoing public interest RD&D efforts conducted by investor-owned utilities prior to the onset of electricity restructuring.

Edison Technology Solutions (ETS) is an unregulated subsidiary of Edison International and an affiliate of Southern California Edison Company (SCE). As a result of a corporate restructuring, ETS ceased active operations on September 30, 1999. ETS' remaining rights and obligations were subsequently transferred to SCE.

What follows is the final report for the Photovoltaics project, 1 of 10 projects conducted by ETS. This project contributes to the Renewable Energy program.

For more information on the PIER Program, please visit the Commission's Web site at: <http://www.energy.ca.gov/research/index.html> or contact the Commission's Publications Unit at 916-654-5200.

Executive Summary

California leads the nation in the production of electricity from renewable sources. However, since the original surge in interest, inspired in part by the Public Utilities Regulatory Policies Act of 1975 (PURPA), the growth of renewable generation capacity within the State has slowed. This may be partly attributed to the economic uncertainty caused by the energy deregulation process.

Currently, the abundance of cheap energy in open markets places significant economic pressure on existing renewable energy generation systems, and new unsubsidized projects are all but unfeasible. This adverse economic environment is severe for systems that use photovoltaic (PV) technology to produce electrical energy.

In 1996, deregulation of California's energy markets began with the passage of Assembly Bill 1890 (AB 1890). The deployment of renewable generation systems, before and since deregulation, has been dependent on special-purchase, operating, and construction subsidies, to encourage continued renewable energy project deployment and research through the Year 2002.

Subsidies are particularly crucial for renewable energy systems using PV technologies. Grid-interactive electrical generation systems based on PV technologies appear unattractive because of the high initial cost of the expensive and complicated manufacturing processes needed to produce the solar energy conversion component. Questions regarding operational reliability, long-term cost/benefit, durability, and safety of PV systems have discouraged their widespread deployment. Low market demand discourages the investments needed to finance manufacturing improvements that would increase yields and lead to unit cost reductions associated with volume production.

In the fully deregulated marketplace, electrical energy produced from PV systems, must meet the market price of energy, which is currently about \$0.12/kWh (kilowatt-hour). The current cost of energy produced from PV systems ranges between \$0.15 and \$0.30 per kWh.

One strategy to increase demand and thus to grow the market for PV technology, is subsidizing the deployment of small and medium-scale PV systems. A second growth strategy is the value-added approach. Many government-sponsored programs partially offset the cost of PV systems by integrating solar conversion components with building materials such as solar shingles, roofing panels, and structural components. Growth of this market segment demands the availability of reliable performance and maintenance data to encourage greater use of these systems.

ETS has a program that includes installations at strategic locations on the distribution system for grid-support, high-profile sites, educational institutions, and residential areas. This project continues the operation and monitoring of five existing PV systems. During the course of this project, seven new additional PV systems were installed and evaluated. This project was funded by a \$1 million PIER Transition grant.

Objectives:

- Evaluate installed system performance and efficiency as compared to expected results.
- Evaluate the effects of weather on year-round PV operations in California.
- Demonstrate the value of PV as a distributed generation resource for grid support and local reliability.
- Improve the performance and reliability of PV systems and components by testing and monitoring PV equipment in the field, and working with manufacturers to solve critical operational problems.
- Develop standard small to medium-sized PV system configurations.
- Increase public awareness and community acceptance of PVs by placing systems in high-profile sites, creating and distributing public information materials, and coordinating the incorporation of PV information within the science curriculum at participating schools.
- Provide written reports on PV systems operational data for public dissemination.

Data Collection Methods:

System energy output for each site was based upon manufacturer's performance specifications for system components, panel orientation, and the exposure to the sun. Power production and environmental data (irradiance, temperature and wind) were collected automatically every 15 minutes with a Data Acquisition System. The data was summarized and plotted monthly, from startup through June 1999, and presented in Appendix I, *Site Power Production Data*.

The output performance data appearing throughout this report should be reviewed with the following cautions. The data available for this report covers a period of less than 1 year. Certain anomalies have been observed that may be related to Data Acquisition System instability or component outage; these are presented in Appendix I, showing the month(s) in which the anomaly was observed.

Outcomes:

- The actual energy generated by the PV equipment tested at 12 field sites was ± 85 percent of that projected by design calculations.
- Seasonal effects on various PV systems showed that with increasing panel temperatures, efficiencies decreased; conversely, when panels were cooler at the same irradiance level, system efficiency increased.
- The Monterey Hills Elementary School and Huntington Library applications best demonstrated the value of PV as a distributed generation resource for grid support and local reliability, with no brown-outs, voltage flickering, or complaints about quality.
- ETS and its partner, Solar Utility, provided performance feedback to inverter manufacturers resulting in timely diagnosis of problems and correction of inverter manufacturing defects.

- ETS developed standard configurations for residential systems and one expandable modular rooftop configuration that is appropriate for public and commercial use.
- ETS increased public awareness and community acceptance of PVs by placing systems in high-profile sites such as Knott's Berry Farm and the Santa Monica Pier, as well as at various educational sites with science curriculum which promoted visibility and exposure to PV technology.
- This report includes an analysis of the data collected, and a summary of the lessons learned during this 1-year project, to fulfill the Final Report requirements of Task 11 – Photovoltaics of Contract 500-97-012 between the California Energy Resources Conservation and Development Commission and Edison Technology Solutions (ETS).

Conclusions:

- The technical and economic outcomes of this project showed that properly designed and situated PV systems, including conventional tilted-array, flat-panel, and building-integrated designs, were shown to operate within an acceptable range of ± 15 percent of their expected efficiency specifications.
- PV systems evaluated under a full range of seasonal variations, operated as projected with increased energy production in the summer and lower energy production during the winter. Longer daylight hours in the summer time increased overall energy production, more than offsetting decreased panel efficiency occasioned by top daytime temperatures. Cell and ambient temperature did in fact have a more significant than expected affect on the panels as evidenced by the lower overall energy production levels. Several sites also experienced severe soiling which reduced the amount of energy the PV system produced.
- ETS provided the PV industry with operational data that they can use to make PV systems more reliable and cost effective, by alerting manufacturers that the inverter was the most troublesome component of other PV systems.
- Of all sites, the Monterey Hills Elementary School and Huntington Library applications best demonstrated that PV is a valuable distributed generation resource for grid support and high-quality local reliability.
- ETS developed small and medium-sized PV systems at multiple sites using off-the-shelf, widely available products. Standard design packages will simplify the materials procurement, reducing the construction time and installation costs of similar future systems. The ease of installation of these standard design configuration systems is expected to encourage market growth, increase demand, and drive unit prices down.
- Demonstration sites selected by ETS to promoted visibility and exposure to PV technology, clearly helped advance the public awareness and acceptance of PVs.

- By exceeding the original stated objectives of this project, the California Energy Commission, along with Edison Technology Solutions have assisted in the advancement of the PV commercialization efforts here in California. The total cost of this project was \$2,427,000. The Commission portion of project cost was \$1 million. Cost sharing funds in the amount of \$1,427,000 were provided by participating agency and industry partners (Table 1).

Table 1. Project Cost Share Distribution

Task #11 – Photovoltaics Participant Funding	
Utility PhotoVoltaic Group (UPVG)	\$200,000
U.S. Department of Energy (DOE)	\$700,000
Emerging Renewables	\$527,000
Total	\$1,427,000

Abstract

ETS has a program that includes installations at strategic locations on the distribution system for grid-support, high-profile sites, educational institutions, and residential areas. This project continues the operation and monitoring of five existing PV systems, and evaluates their performance and efficiency. The seasonal effects of year-round PV operation in California will also be evaluated. During the course of this project, several new additional PV systems were installed and evaluated. Funded by the California Energy Commission, the project undertook the operation and monitoring of prototypical small to medium-sized grid-connected PV electric power generating facilities in Southern California to evaluate their year-round performance and efficiency. The funding period was from May 1998 through September 1999.

1.0 Introduction

Prior to the restructuring of California's electricity industry in 1996, ratepayer-funded energy-related RD&D projects were primarily conducted by the state's regulated utilities. Under this arrangement, California led the nation in developing and deploying a wide range of innovative and environmentally sound energy technologies. These efforts resulted in more than a billion dollars of savings for ratepayers by the deployment of improved generation methods and/or more efficient end-use strategies. (Reference: *1998 Annual Report Concerning the Public Interest Energy Research Program*. The California Energy Commission; March 17, 1999, Executive Summary, page ES-1.)

In 1996, the California Legislature restructured the State's electricity services industry by the passage of AB 1890. This legislation expressly directed that existing industry-related RD&D activities, which served a broad public interest, "should not be lost in the transition to a more competitive environment."

Recognizing California Energy Commission's longstanding and widely acknowledged leadership role in energy-related RD&D activities, the Legislature transferred funds to the Commission to support PIER program. PIER funds are earmarked for the support of those public interest RD&D activities that are not likely to be adequately funded by the competitive or deregulated marketplace.

To implement its responsibilities for public interest research effectively, the Commission prepared an RD&D Strategic Plan which, in part, determined that one goal of the PIER funding initiative should be the expansion and retention of benefits provided by the state's fledgling renewable energy industry. One of the renewable energy technologies targeted for funding was the direct production of electrical energy from sunlight by the use of PV devices. The main benefit that this technology provides to California is that it does not release pollutants into the air.

Historically, much of the industry-sponsored RD&D effort for PV deployment has been directed toward the development of megawatt scale PV applications. Recently, the industry has come to understand that the future viability of PV is dependent upon market growth and that growth must come from the small to medium-scale applications, instead of utility scale applications.

Small array and building-integrated material systems have been shown to be technologically feasible and there is a market niche for complete stand-alone systems that can be easily installed and maintained by do-it-yourself users. However, questions about their ease of assembly, reliability, energy output and practicality need to be answered. Moreover, the high cost of these systems must be reduced for these applications to be attractive in the unsubsidized marketplace.

1.1 Project Purpose

The purpose of this project was as follows:

- Learn how PV systems operate once installed in the field.
- Learn how weather impacts the year-round operation of PV systems.
- Provide the PV industry with operational data that they can use to make PV systems more reliable and cost effective.

Under current market conditions, the abundance of cheap utility power and the relatively high costs associated with PV applications have combined to limit the deployment of this renewable energy technology. The high cost of PV systems is directly attributable to the complicated and expensive process currently used to produce the PV materials. Theoretically, current-manufacturing processes could be made more efficient and less costly by incorporating advance production techniques and increasing batch size to increase production yields. Reductions in manufacturing costs are expected to result in lower unit and system costs.

Realization of the potential manufacturing efficiencies necessary for production improvement and upgrade will require a substantial infusion of capital. Presently, the current low level of demand for PV systems discourages the requisite investment.

1.2 Project Objectives

This PIER Transition-funded project is one of the California Energy Commission's continuing efforts to stimulate market demand for PV systems. The specific technical objectives of this task were as follows:

- Evaluating system performance and efficiency by comparing them to expected results.
- Evaluating the seasonal effects of year-round PV operations in California.
- Provide written report findings for public dissemination.

Additionally, by performing these project objectives, ETS was also able to accomplish the following program objectives:

- Demonstrate the value of PV as a distributed generation resource for grid support and local reliability.
- Develop standard small to medium-sized PV system configurations.
- Increase public awareness and community acceptance of PVs by placing systems in high-profile sites, creating and distributing public information materials, and coordinating the incorporation of PV information within science curriculum at participating schools.
- Improve the performance and reliability of PV systems and components by testing and monitoring PV equipment in the field.
- Measure the benefits to California, including air quality and the reliability of PV as a distributive generation resource.

1.3 Purpose and Organization of This Report

This report documents PV systems design, hardware, and operational lessons learned, to make the information available to those who will undertake similar studies in the future.

The report is organized into: Introduction, Project Approach, Site Applications, Lessons Learned, Conclusions, and Appendix I. The Project Approach sections on selected sites are: Grid Support – Transmission and Distribution System Deferral; Standardized Design Packages; High-Impact Public Visibility Sites, and Educational Settings. Appendix I contains the site power production data.

2.0 Project Approach

2.1 Design Philosophy

This project task evolved from RD&D activities originally begun by Southern California Edison as a regulated utility. The original design philosophy during that period emphasized distributed generation grid support applications. Two of the applications, Huntington Library and Monterey Hills Elementary School, included within this project, reflect the earlier distributed generation objectives of the utility and were undertaken to offset the need for transmission system extension and upgrade.

Under this project, the ETS design philosophy was to continue to locate PVs on the distribution system for grid support, and expanded to include installations at high profile sites, educational institutions and residential areas. Highly visible sites were selected to deploy systems in conjunction with public information and education programs.

2.2 Design Specification

The design approach for ETS solar installations incorporates several preliminary site selection activities. Site feasibility studies include estimates of solar exposure, security, public visibility, and opportunities to demonstrate high impact uses of solar energy to meet consumer demand. The site evaluation procedure also includes a preliminary structural integrity analysis of existing buildings that may be used to support various PV systems.

Unique site considerations have also favored the use of some materials over others. In settings at high risk for vandalism, the use of thin-film technologies integrated with building materials presents a decided advantage over panels fabricated with single crystal solar cells that are highly susceptible to breakage.

The PV packages installed by ETS represented an attempt to maintain diversity in the selection of collector systems. The program used single crystal, poly crystal, and thin film collector technologies in tilted array, flat plane, and building materials integrated configurations. Moreover, in this project, ETS made an effort to use power-conditioning components, provided by a number of manufacturers.

To fairly evaluate the power conditioning components available, ETS used OMNION, TRACE, and ABACUS inverters. Moreover, ETS worked with the manufacturers to identify and correct potential problems with their equipment. Some of these improvements are currently being incorporated into the design manufacturing process.

2.3 Acceptance Test Procedures

Subsequent to the completion of the installation of the PV systems, ETS conducted acceptance testing of each system in order to verify their operating conditions and system performance. The acceptance tests were based on procedures established by the Utility PhotoVoltaic Group (UPVG) as part of their Team-Up Program. The steps included:

- Visual inspection of the installation: verify that the physical structure has been properly installed, grounded, and oriented.

- Testing of system components: verify proper operation of disconnect switches (both DC and AC), and inverter(s); e.g., the DC switch should disconnect the DC power from the inverter, the AC switch should disconnect the inverter from the utility grid, and the inverter should perform its functions in accordance with manufacturers specifications.
- Performance verification: verify that the energy and environmental measurements taken by the Data Acquisition System were compared to reference measurement equipment.

2.4 Data Acquisition Methodology

Systems equipped with a Data Acquisition System enable the continuous performance monitoring of PV systems over a period of time. Data Acquisition System consists of a data-logger, a telephone modem, environmental sensors, and a method of measuring energy output. Environmental measurements are sampled every 5 seconds, then averaged over 15 minute intervals. Energy measurements are digital pulse outputs that correspond to energy in kilowatt-hours; these pulses were totalized every 15 minutes. The data-logger stores a data packet every 15 minutes in its memory. A central server dials into each PV system nightly to download the past 24 hours of data.

Environmental sensors consist of the following:

- Thermocouples: measures ambient and panel temperatures
- Pyranometer: measures solar irradiance
- Anemometer: measures wind speed.

Each month, a summary report was prepared and used for analysis purposes. Any anomalies in the data, and deficiencies with operation of a system were reported. In addition, monthly and daily calculations were conducted to characterize the performance of a system for each month. Additional charts provided a graphical view of system performance.

2.5 Site and System Selection Considerations

Demonstration sites were selected on the basis of customer interest, high visibility, and potential to enhance public information/awareness campaigns or to support coordinated educational objectives. The site selection process was driven by the concept that PV systems must ultimately be packaged for the consumer marketplace to create the necessary demand to generate potential manufacturing economies of scale. Based on this concept, small and medium-sized packages were developed for both residential and commercial installations.

The high cost of custom designing site-specific solar installations could be alleviated by the development of standard packages. Standard packages can be easily incorporated into building design by architects, engineers, remodelers, and contractors without requiring a comprehensive knowledge of PV. Standard packages were developed for modular commercial flat roof systems, solar patio covers, residential flat garage roof installations, and an expandable roof shingle system using integrated building materials.

Systems included in this project are summarily described in Section 3.

3.0 Site Applications

3.1 Grid Support – Transmission and Distribution System Deferral

The Monterey Hills Elementary School and the Huntington Library systems were installed to defer a costly and environmentally disruptive upgrade to an existing capacity-constrained feeder system. These grid-connected distributed generation PV facilities were situated in mature upscale neighborhoods that are typical of some Edison service areas where underground feeder cables were first installed many years ago.

The service area selected for viability demonstration of PV grid-support distributed generation applications is currently experiencing significant home remodeling and expansion activities that are expanding living space by 50 to 100 percent. While most projects are energy-conscience and employ energy-efficient insulation, windows, and appliances, site net energy use usually increases because remodeling or expansion may include an air conditioner where none existed before.

The targeted service areas are presently fed by 4 kV (kilovolt) underground distribution systems. From a practical perspective, these systems cannot be expanded and must be dug up and replaced. The reason is that when these systems were originally installed, they used copper cable with custom conduits. Modern under-grounding uses 12 or 16 kV aluminum cable that is pulled through larger, well-designed conduits.

The cost of replacing existing feeders is very high because public underground right-of-ways are crowded with sewers, water mains, telephone cables, and gas lines. Moreover, the cost associated with coordinating replacement activities to minimize community disruption is extremely high and PV appears to be a highly acceptable alternative.

However, PV is not automatically the right choice; many other factors must be considered. For example, if the circuit demand peaks at night, PV will be of little use. If there is no exposure to the sun, PV will not work. Finally, real estate may be expensive, even if it involves nothing more than the use of roof space.

System peaks depend upon location, residential/commercial mix, lifestyle, income levels, and several other factors. Some individual circuit peaks on Edison's system occur soon after noon, some between 3 p.m. and 4 p.m., and others at sundown or even later. The peak usage periods along the circuits selected for the demonstration site are driven by air conditioning demands that usually begin in the early afternoon and extend into the early evening. During these high-demand periods, PV can provide important grid support. (Reference: Southern California Edison, U.S. Department of Energy: *On-Grid PV Implementation Program, Phase I Report*, November 29, 1994.)

Each of the graphs displayed in Sections 3.1.1 through 3.4.4 refer to the period from August 1998 through June 1999. The monthly bar labeled "Energy Projected" represents estimates of system output that were prepared as part of the design process. The output estimate was calculated using component conversion factors and estimates of solar exposure for each system. Solar exposure estimates were calculated on the basis of system location, array orientation, array tilt, and shading factors where appropriate.

The "Energy Produced" bars, displayed by the graphs in Section 3.1.1 through 3.4.4, represents actual system output collected by individual site Data Acquisition Systems. Most Data Acquisition Systems were deployed and calibrated after August 1998. As a

consequence, the “Energy Produced” bars displayed for each site represents actual power output data collected since operation began.

3.1.1 Monterey Hills Elementary School

This facility was originally installed by Southern California Edison in 1995 as part of the Solar Neighborhood Program to preclude a costly transmission system upgrade to meet the increased energy demands of the school.

The system at this site is comprised of two separate arrays (Figure 1). The larger array consists of 1,818 Siemens SM55 Modules with Standard Test Condition (STC) ratings of 55 watts each for an array total of 99.9 kW output. The smaller and older array includes 240 MSX-64 Modules producing an array total of 15.4 kW output. 570 panels face south, and 1,488 panels face west. This orientation prevents the system from reaching its maximum array output.



Figure 1. Monterey Hills Elementary School

Additionally, this site has been experiencing a major inverter problem related to the cooling system components in the Omnion 2400 Series. Please refer to Section 4.3.2 for additional details. The low readings for January and February 1998 are caused by multiple inverter failures.

Power conditioning is accomplished by the use of 16 to 6 kW Omnion Series 2400, and 2 5 kW Abacus Inverters. Production and environmental data are collected in 15-minute increments by an automatic Data Acquisition System.

(Table 2) summarizes the technical characteristics of this facility.

Table 2. Monterey Hills Elementary School System Description

Location: South Pasadena, California			
Array Size:	115.3 kW	Annual Energy Projection:	133,868 kWh
Panel Manufacturer:	Siemens SM55 Solorex MSX-64	Number of Panels:	1,818 240
Inverter Manufacturer:	Omnion (Qty. 16) Abacus (Qty. 2)	Model:	6 kW Series 2400 5 kW
DAS Manufacturer:	Campbell Scientific	Model:	CR10X

Figure 2 illustrates this site's average monthly energy production.

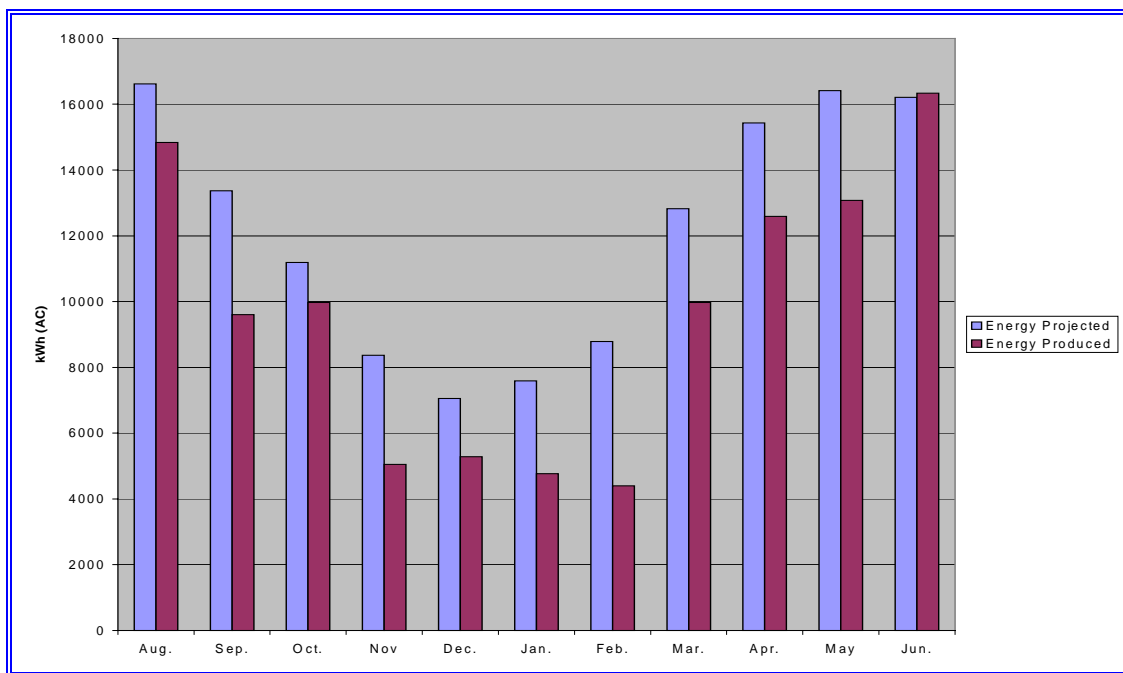


Figure 2. Monterey Hills Elementary School Energy Profile

3.1.2 Huntington Library

This facility was also originally installed in 1996 under Southern California Edison's Solar Neighborhood Program. The existing Edison distribution subsystem, serving the Huntington Library, is part of the oldest underground cabling system in the SCE service territory.

The installed PV system was designed to defer cable replacement or upgrade and increase reliability of the local system Figure 3. The installed system is comprised of 1,092 SOLEC SQ-090 Single Crystal Modules with STC rating of 90 watts each, that produce an array total output of 98.3 kW. The low reading for April 1999 is due to data logger outage. Due to the need to have maximum power during the mid-afternoon

hours, this entire array is west facing. This orientation prevents the system from reaching its maximum array output.



Figure 3. Huntington Library PV System

Power conditioning is accomplished by the use of 13 to 5 kW Omnion Series 2400 Inverters. Production and environmental data are collected in 15-minute increments by an automatic Data Acquisition System.

Table 3 summarizes the technical characteristics of this facility.

Table 3. Huntington Library System Description

Location: San Marino, California			
Array Size:	98.3 kW	Annual Energy Projection:	101,154 kWh
Panel Manufacturer:	Solec SQ-090	Number of Modules:	1,092
Inverter Manufacturer:	Omnion (Qty. 13)	Model:	5 kW Series 2400
DAS Manufacturer:	Campbell Scientific	Model:	CR10X

Figure 4 illustrates this site's average monthly energy production.

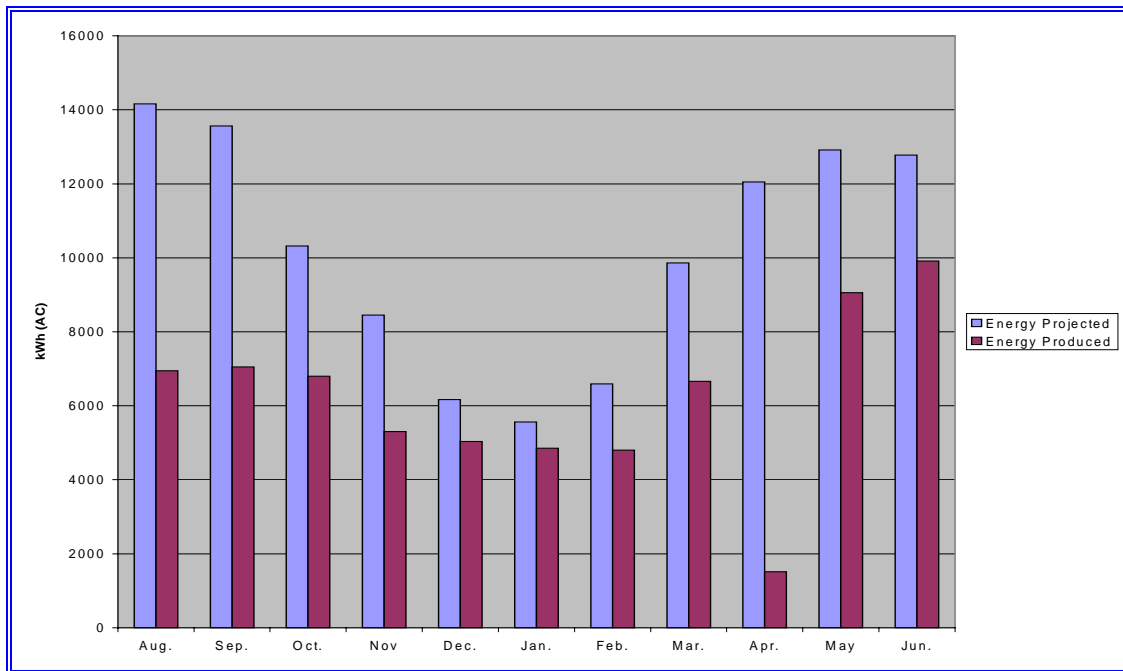


Figure 4. Huntington Library PV System Energy Profile

3.2 Standardized Design Packages

An important objective of this project involved the development of standardized application packages to eliminate the high cost of custom site design. Standard packages can be easily incorporated into building design by architects, engineers, remodelers, and contractors without requiring a comprehensive knowledge of PV. Standard packages were developed for modular commercial flat roof systems, solar patio covers, residential flat garage roof installations, and an expandable roof shingle system using integrated building materials.

3.2.1 Elizabeth Court

This installation site was the location of an affordable housing complex. The PV system was funded with a participating contribution from the U.S. Department of Energy (DOE). The project was conceptualized as a vehicle to present a working PV system to a segment of the population least likely to be familiar with this technology.

The system is a rooftop mounted tilted array, consisting of 96 Siemens SP-75 PV modules rated at 7.2 kW STC (Figure 5).



Figure 5. Elizabeth Court Rooftop PV System

ETS had this system designed as an easily replicable modular PV system for installation onto commercial flat roofs. This system was to form the basis of an off-the-shelf design to eliminate a costly part of PV system acquisition. This site demonstrated the combination of two separate modules, a 2.2 kW PV system module, and a 5 kW PV system module. Future sites can be designed by combining any number of these modules until the desired output is obtained. Commercial flat roofs vary greatly in size, and a modular approach gives maximum design flexibility while eliminating the expense of custom designs.

Power conditioning is accomplished by the use of one 5 kW Series 2400 and one 2.2 kW Series 2400 Inverters. Production and environmental data are collected in 15-minute increments by an automatic Data Acquisition System. Table 4 summarizes the technical characteristics of this facility.

Table 4. Elizabeth Court Rooftop System Description

Location: Cudahy, California			
Array Size:	7.2 kW	Annual Energy Projection:	9,531 kWh
Panel Manufacturer:	Siemens SP-75	Number of Modules:	96
Inverter Manufacturer:	Omnion (Qty. 1) Omnion (Qty. 1)	Model:	5 kW Series 2400 2.2 kW Series 2400
DAS Manufacturer:	Campbell Scientific	Model:	CR500 30

Figure 6 illustrates this site's average monthly energy production.

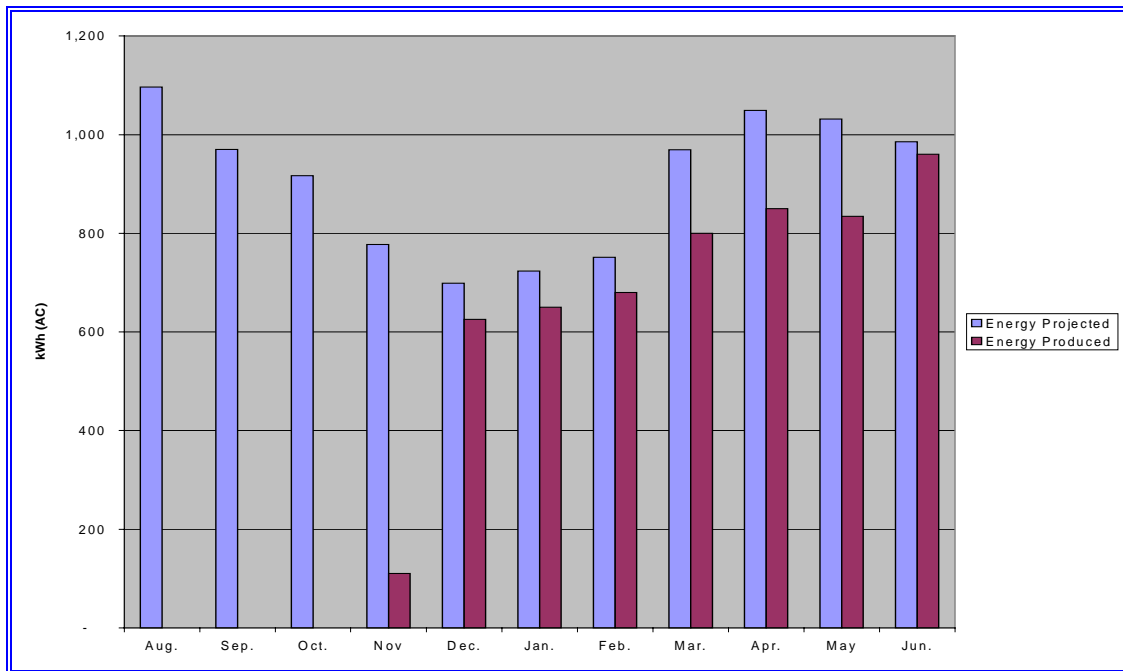


Figure 6. Elizabeth Court Rooftop PV System Energy Profile

3.2.2 Standard Residential Patio Cover System

In conjunction with its partner Solar Utility Company, Inc., ETS configured a patio cover system using United Solar SSR-120 PV thin-film Modules bonded to standard, standing-seam aluminum roofing panels, rated at 2.2 kW STC (Figure 7). Because this flat panel system contains no glass, it is highly durable; moreover, panels are available in a variety of standard architectural colors. The system can be used for either replacement of existing patio covers or as part of a new structure.



Figure 7. Residential Patio Cover System

This site has experienced a severe soiling and debris problem. Leaves and dust from the neighborhood continuously cover the patio, resulting in lower energy production. The patio roof panels are mounted at a 5 degree tilt, and incur some shading in the late afternoon. Patio roofs vary considerably in size and shape. ETS designed this system with a 4 kW inverter that is capable of accommodating patio roofs up to 800 square feet. For many patios, the inverter will be oversized. However, the incremental cost of purchasing this oversized inverter is more than offset by the elimination of custom design costs. This results in a net savings to the end user while giving the maximum design size flexibility to architects, engineers, remodelers, and contractors.

Power conditioning is accomplished by the use of one 4 kW Trace UT SW 4048UPV Inverter. Production and environmental data are collected in 15-minute increments by an automatic Data Acquisition System. Table 5 summarizes the technical characteristics of this facility.

Table 5. Residential Patio Cover System Description

Location: Monrovia, California			
Array Size:	2.2 kW	Annual Energy Projection:	3,044 kWh
Panel Manufacturer:	United Solar SSR-120	Number of Modules:	18
Inverter Manufacturer:	Trace (Qty. 1)	Model:	UT SW 4048UPV
DAS Manufacturer:	Campbell Scientific	Model:	CR500

Figure 8 illustrates this site's average monthly energy production.

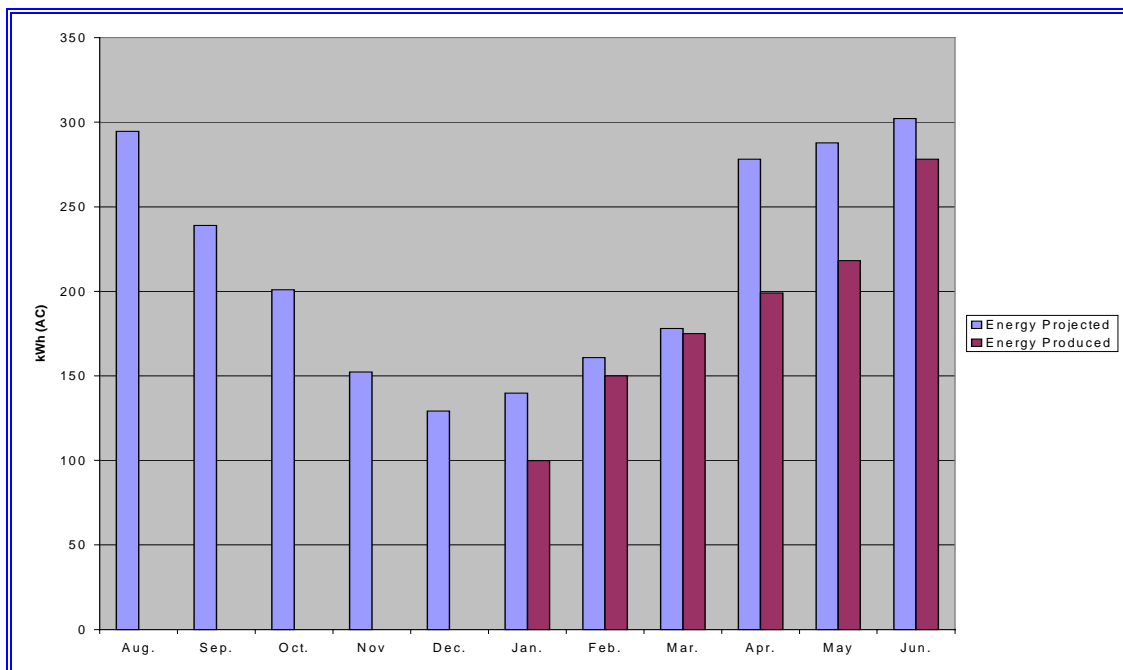


Figure 8. Residential Patio Cover System Energy Profile

3.2.3 Standard Residential Garage-Mount System

This standard package employs a roof-mounted tilted array system that is attached to a standard flat garage by a galvanized pipe mounting structure (Figure 9). The array consists of 24 Siemens SR-100 Modules, configured into two source circuits, rated at 2.4 kW STC. The mounting structure is connected to the carport roof using watertight roofing mounts lag-bolted to the garage roof rafters. ETS designed this system to fit on a typical flat roofed, two-car garage. It uses mounting hardware widely available at hardware stores and home centers (such as Home Depot). It was envisioned that this system would be the basis for a do-it-yourself PV system.



Figure 9. Standard Residential Flat Roof Garage Mount System

Power conditioning is accomplished by the use of one 2.2 kW Omnion Series 2400 Inverter. Production and environmental data are collected in 15-minute increments by an automatic Data Acquisition System. Table 6 summarizes the technical characteristics of this facility.

Table 6. Flat Panel Garage-Mount System Description

Location: Chino Hills, California			
Array Size:	2.4 kW	Annual Energy Projection:	3,493 kWh
Panel Manufacturer:	Siemens SR-100	Number of Modules:	24
Inverter Manufacturer:	Omnion (Qty. 1)	Model:	2.2 kW Series 2400
DAS Manufacturer:	Campbell Scientific	Model:	CR500

Figure 10 illustrates this site's average monthly energy production.

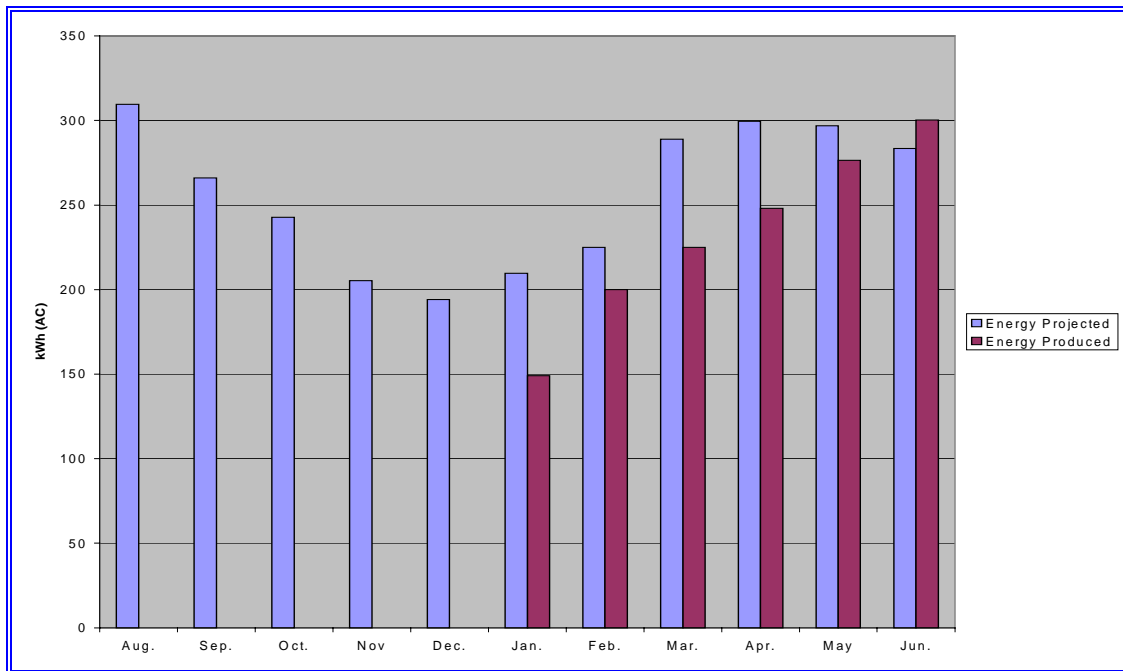


Figure 10. Standard Residential Flat Roof Garage Mount System Energy Profile

3.2.4 Straw Bale House

The Straw Bale House system, rated at 1.6 kW STC, is a PV roof shingle system consisting of 96 United Solar SHR-17 shingles (Figure 11). Each shingle is a triple-junction amorphous silicon alloy cell that is interconnected with bypass diodes and laminated to form a dimensional shingle that can be applied to conventional roof decking surfaces using common roofing nails. Roof shingles have the potential of being the most versatile PV building integrated product. There are virtually no limitations to the size and shape of the PV array. This product easily replaces common composition roofing shingles without affecting the existing roofing structure, design or integrity. This ETS design is expanded by the simple addition of more shingles up to 4kW.



Figure 11. California Polytechnic Straw Bale House Shingle System

Power conditioning is accomplished by the use of 1-4 kW Trace SW 4048PV Inverter. Production and environmental data are collected in 15-minute increments by an automatic Data Acquisition System. Table 7 summarizes the technical characteristics of this facility.

Table 7. Cal Polytechnic Straw Bale House System Description

Location: Pomona, California			
Array Size:	1.6 kW	Annual Energy Projection:	2,648 kWh
Panel Manufacturer:	United Solar SHR-17	Number of Modules:	96
Inverter Manufacturer:	Trace (Qty. 1)	Model:	4 kW SW 4048PV
DAS Manufacturer:	Campbell Scientific	Model:	CR500

Figure 12 illustrates this site's average monthly energy production.

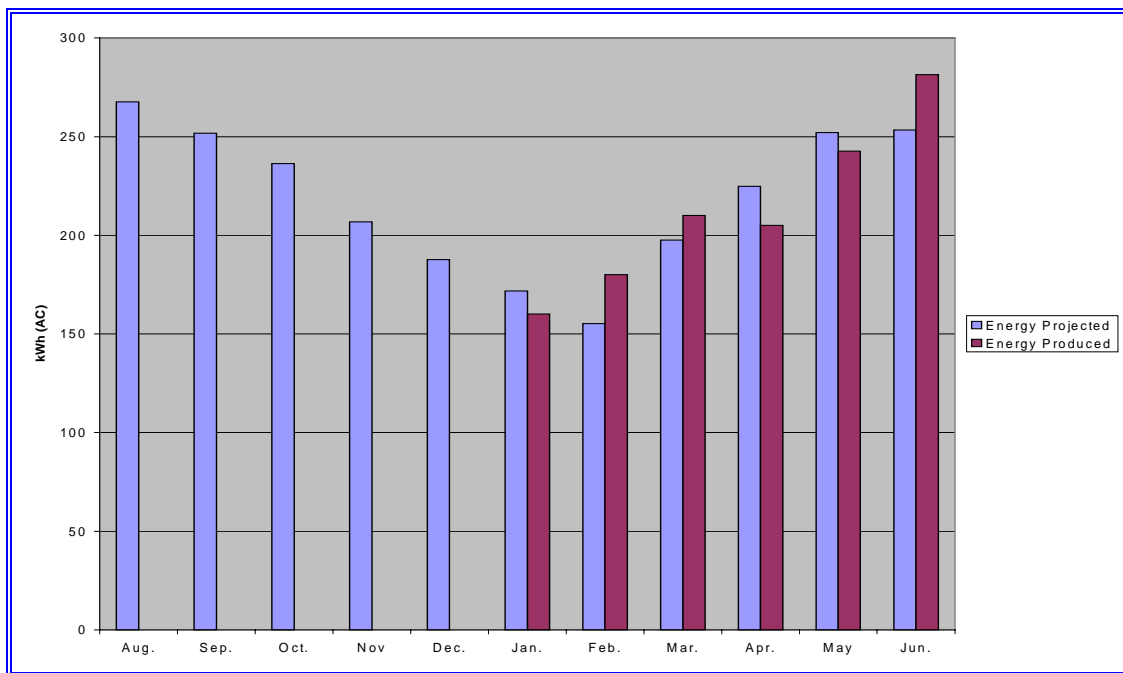


Figure 12. Cal Polytechnic Straw Bale House Shingle System Energy Profile

3.3 High-Impact, Public Visibility Sites

In response to the program goal of increasing public awareness and community acceptance of PV technology through the installation of systems in high-profile sites, ETS developed applications at Knott's Berry Farm and Santa Monica Pier. The locations selected for each of these applications are visited by millions of people each year. The Santa Monica Pier is equipped with a dynamic Kiosk information system designed to make each visit a memorable experience.

In addition to the sites and applications discussed in this report, ETS is developing high-impact projects at other locations. These projects each use differing forms of PV application technology. The Santa Monica Civic Center will present an example of thin-film-laminated, building-integrated materials in the form of a standing seam metal roof application. The Chabot Observatory will use the PowerGuard roofing system, which simultaneously produces power from PV technology while providing insulation from climatic temperature extremes. The Discovery Science Center ("The Cube") will use the flat-panel technology in a combined educational and aesthetic application that will highlight the ETS contribution to the "Cube." These projects are also combined with either passive information delivery systems or formal educational modules that present facts about PV technology and the environmental benefits associated with its use.

The Knott's Berry Farm and Santa Monica Pier applications are discussed in Sections 3.3.1 and 3.3.2.

3.3.1 Knott's Berry Farm

The Park attracts more than a million visitors each year and is home to the longest wooden roller coaster on the West Coast. Two of the Park's premier attractions are the Thomas A. Edison Workshop and the nightly Edison International Electric Light show.

The Knott's Berry Farm site has a large PV array mounted on the roof of the Company Store building (Figure 13). Output from this system is conditioned and fed into the Park's distribution system for use throughout the park. The system consists of 462 Siemens SP-75 Modules, rated at 34.7 kW STC.



Figure 13. Knott's Berry Farm Company Store

Power conditioning is accomplished by the use of seven 5 kW Omnion Series 2400 Inverters. Production and environmental data are collected in 15-minute increments by an automatic Data Acquisition System. Table 8 summarizes the technical characteristics of this facility.

Table 8. Knott's Berry Farm (Company Store) System Description

Location: Buena Park, California			
Array Size:	34.7 kW	Annual Energy Projection:	56,645 kWh
Panel Manufacturer:	Siemens SP-75	Number of Modules:	462
Inverter Manufacturer:	Omnion (Qty. 7)	Model:	5 kW Series 2400
DAS Manufacturer:	Campbell Scientific	Model:	CR10X

Figure 14 illustrates this site's average monthly energy production.

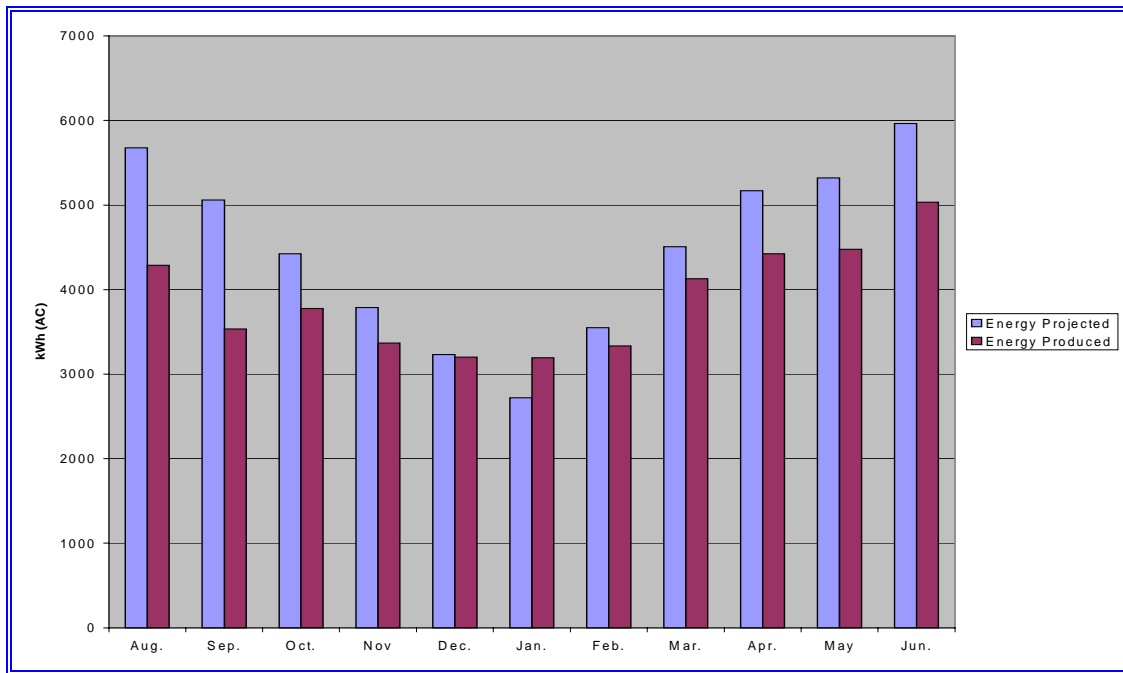


Figure 14. Knott's Berry Farm Company Store Energy Profile

3.3.2 Pacific Park, Santa Monica Pier

Pacific Park is an old-fashioned amusement park that is situated at the end of Santa Monica Pier in Santa Monica, California. The site attracts more than a million visitors each year and is the West Coast's only amusement park actually located on a pier. The Park boasts a long list of exclusive attractions such as having the only roller coaster situated right on a pier and the only Ferris wheel powered by PV. The roller coaster rises five stories above the ocean and makes two 360-degree turns directly above two of the Park's other rides. The Pacific Wheel is California's only giant Ferris wheel. At night, the wheel is lit by more than 6,000 incandescent multi-colored light bulbs that create a spectacular light show. This location's visibility extends beyond Santa Monica through the media of film and television.

In addition to the high impact and public visibility of this site, the installed PV systems are situated in a rigorous environment with climatic conditions typical of California's coast. Environmental conditions of concern include frequent cloudiness or overcast conditions, constant exposure to salt-laden air, and occasional high winds that accompany coastal storms.

Three distributed array configurations, situated on the roofs of several Park structures, have been combined into one integrated system (Figure 15). One of the arrays is configured with a flat geometry while the remaining two are tilted at 15 and 30 degrees respectively. Power conditioning and data acquisition is centralized for each of the configurations. The power produced is fed to a local on-site distribution station.



Figure 15. Santa Monica Pier Full Site

An information kiosk situated at the base of the Ferris wheel provides an assortment of educational materials on PV energy generation including specific site information and contact instructions for visitors to obtain additional information about PV generation issues in general. The system consists of 550 Siemens SP-75 Modules, rated at 41.3 kW STC. Power conditioning is accomplished by the use of nine 5 kW Omnion Series 2400 Inverters. Production and environmental data are collected in 15-minute increments by an automatic Data Acquisition System. Table 9 summarizes the technical characteristics of this facility.

Table 9. Santa Monica Pier System Description

Location: Santa Monica, California			
Array Size:	41.3 kW	Annual Energy Projection:	56,945 kWh
Panel Manufacturer:	Siemens SP-75	Number of Modules:	550
Inverter Manufacturer:	Omnion (Qty. 9)	Model:	5 kW Series 2400
DAS Manufacturer:	Campbell Scientific	Model:	CR10X

Figure 16 illustrates this site's average monthly energy production.

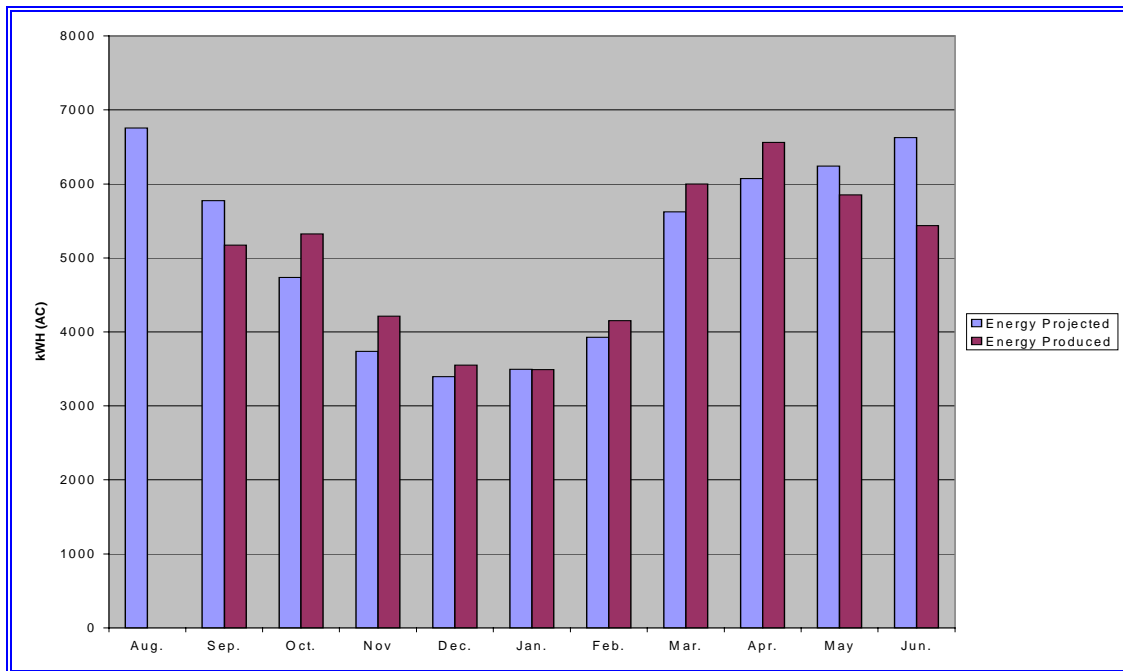


Figure 16. Santa Monica Pier PV System Energy Profile

3.4 Educational Settings

3.4.1 Glenmeade Elementary School

This project was conceptualized under the SCE Solar Neighborhood Program and completed as one of the ETS first projects (Figure 17). This application uses thin-film PV material that is applied to standing seam roof panels. However, these panels are not mounted directly to the roof, as is the case with most applications of this technology. Rather, the panels serve as the actual roof. They are assembled in a rack array that is tilted to maximize exposure to the sun. The presence of this system at an elementary school adds to the visibility and exposure that ETS is giving to PV technology. Schools serve as a showcase for the benefits that PVs bring to our future leaders. Many of the schools that participate in the ETS Solar Neighborhood Program end up expanding their science curriculum to include lessons on solar energy. At Glenmeade Elementary, the PV system utilized a standard building integrated material that served as a shelter from the weather. This allowed the students to assemble under the structure, especially on days with blistering sun or constant rain showers.



Figure 17. Glenmeade Elementary School

The system consists of 96 United Solar SSR-120 Modules, rated at 11.5 kW STC. Power conditioning is accomplished by the use of an 11.5 kW Trace SW 5548PV Inverter. Production and environmental data are collected in 15-minute increments by an automatic Data Acquisition System. Table 10 summarizes the technical characteristics of this facility.

Table 10. Glenmeade Elementary School System Description

Location: Chino Hills, California			
Array Size:	11.5 kW	Annual Energy Projection:	16,500 kWh
Panel Manufacturer:	United Solar SSR-120	Number of Modules:	96
Inverter Manufacturer:	Trace (Qty. 1)	Model:	5 kW SW 5548PV
DAS Manufacturer:	Campbell Scientific	Model:	CR10X

Figure 18 illustrates the Glenmeade Elementary School's average monthly energy production.

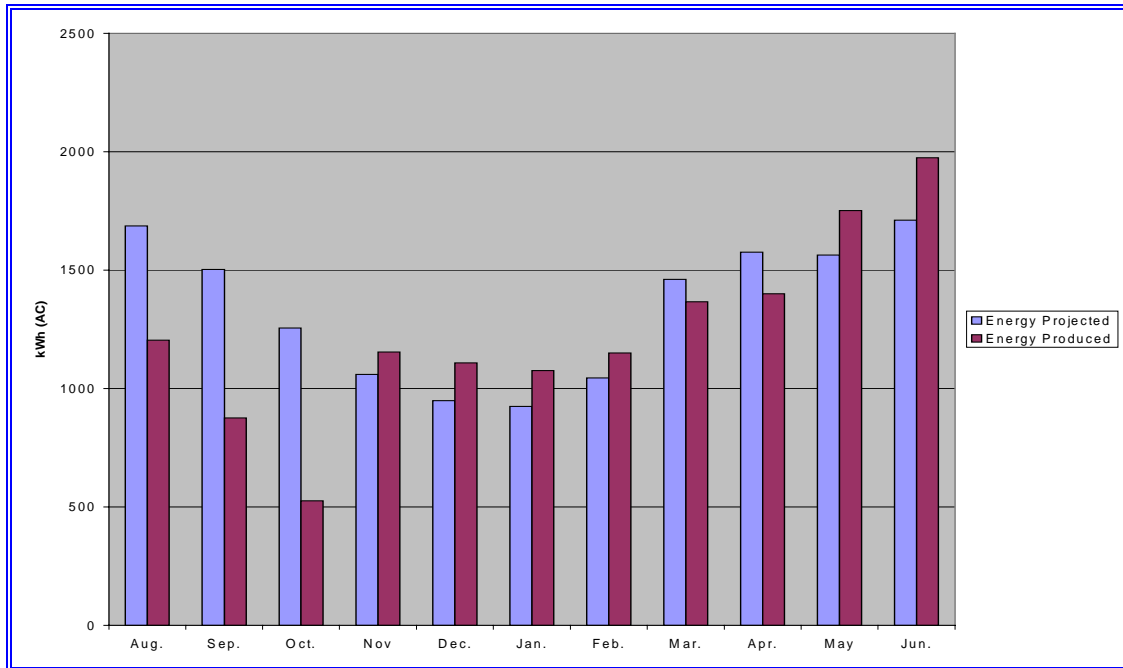


Figure 18. Glenmeade Elementary Roof Panel System

3.4.2 University of California, Irvine

The University of California, Irvine's Combustion Laboratory is the preeminent research facility for electrical energy power production on the West Coast. The installation at UCI employs an innovative building material integrated product consisting of a PV module laminated to a structural steel standing seam roofing panel designed for use on commercial buildings, covered parking systems, fueling depots and other similar structures. This particular PV structure serves as a covered patio that extends over the upper balcony of the combustion laboratory. Since work space at the University is at a premium, this additional covered working area allowed for the installation and testing of two micro-turbine generators (MTG). This PV system, along with MTG's, Fuel Cells, and other advanced technologies being tested there, served as an excellent educational tool for the students. This facility includes 32 SSR-120 and 32 SSR-60 wired in series, rated at 5.8 kW STC.



Figure 19. University of California, Irvine Solar Deck

Power conditioning is accomplished by the use of one 5 kW Trace SW 5548PV Inverter. Inverter is equipped with a ground fault interrupt (GFI) protection circuit. Production and environmental data are collected in 15-minute increments by an automatic Data Acquisition System. Table 11 summarizes the technical characteristics of this facility.

Table 11. UC Irvine Integrated Materials Solar Deck System Description

Location: Irvine, California			
Array Size:	5.8 kW	Annual Energy Projection:	7,838 kWh
Panel Manufacturer:	United Solar SSR-120 United Solar SSR-60	Number of Modules:	32 32
Inverter Manufacturer:	Trace (Qty. 1)	Model:	5 kW SW 5548PV
DAS Manufacturer:	Campbell Scientific	Model:	CR10X

Figure 20 illustrates this site's average monthly energy production.

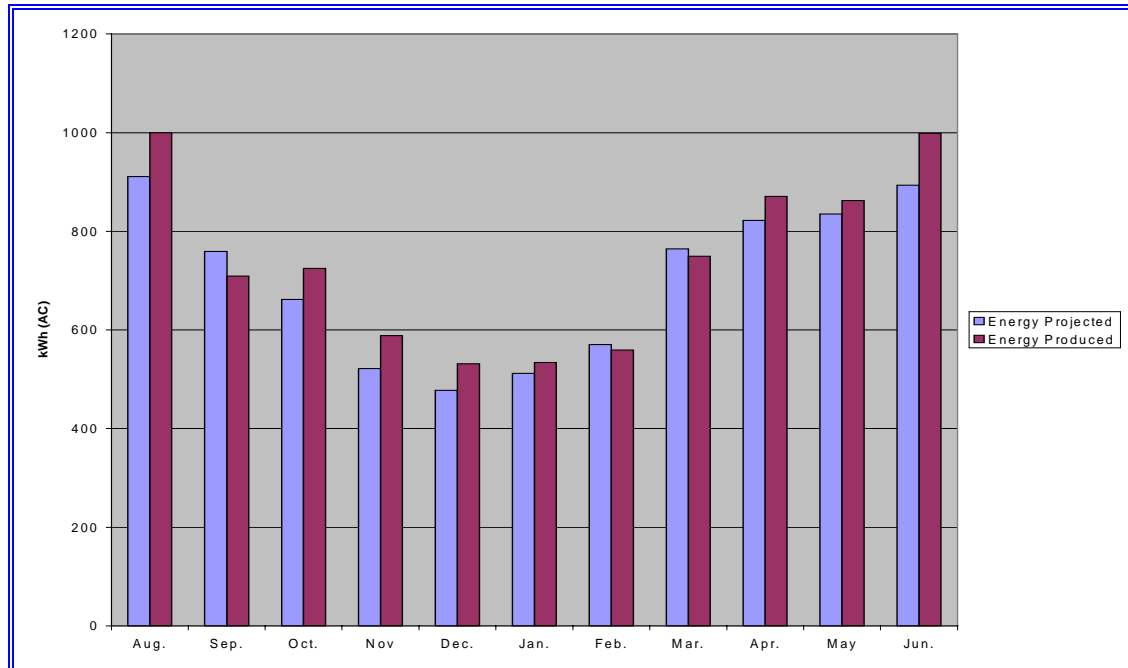


Figure 20. University of California, Irvine Solar Deck Energy Profile

3.4.3 Alamitos Intermediate School

The installation of a PV covered lunch shelter for the student body at this Orange County intermediate school, located in Garden Grove, was the second lunch shelter program. This PV system serves as the largest school lunch shelter in the State of California (Figure 21). The faculty and students have embraced the PV technology, and it is part of their science curriculum for seventh graders. This is the only PV site that has had panels broken by rock-throwing weekend vandals. The school district is addressing these vandalism concerns and does not anticipate any future panels getting broken.



Figure 21. Alamitos Intermediate Covered Lunch Shelter

The Alamos Intermediate School system consists of 168 Siemens SP-75 Modules, rated at 12.6 kW STC. Power conditioning is accomplished by the use of two 5 kW Trace 5548PV Inverters. Production and environmental data are collected in 15-minute increments by an automatic Data Acquisition System. Table 12 summarizes the technical characteristics of this facility.

Table 12. Alamos Intermediate School System Description

Location: Garden Grove, California			
Array Size:	12.6 kW	Annual Energy Projection:	18,713 kWh
Panel Manufacturer:	Siemens SP-75	Number of Modules:	168
Inverter Manufacturer:	Trace (Qty. 2)	Model:	5 kW 5548PV
DAS Manufacturer:	Campbell Scientific	Model:	CR10X

Figure 22 illustrates this site's average monthly energy production.

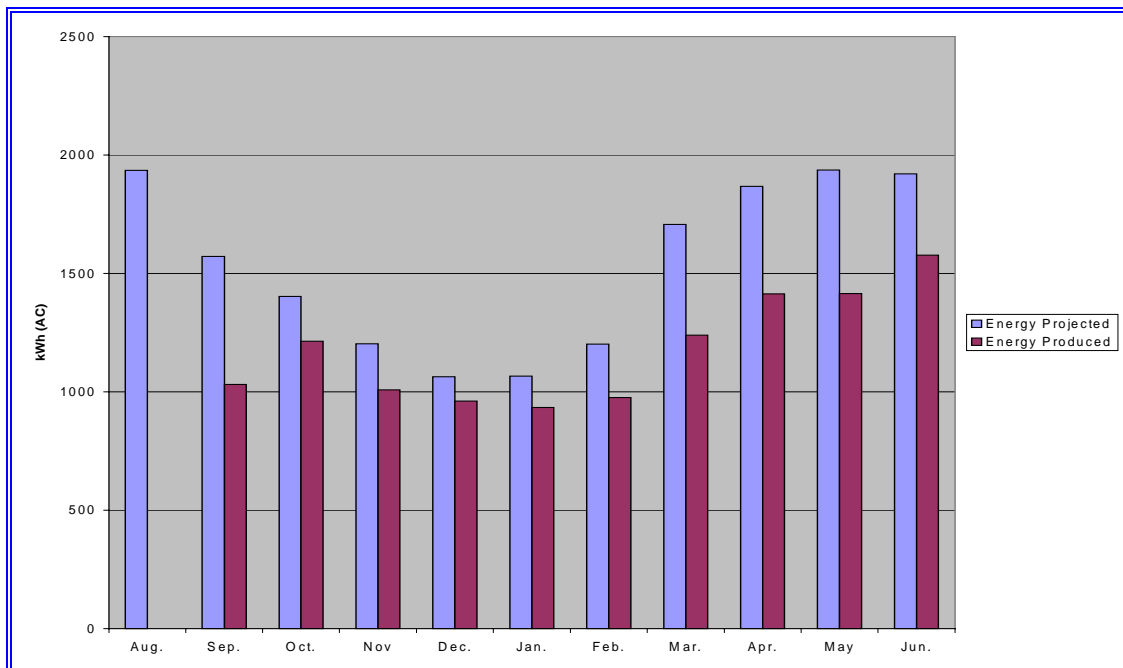


Figure 22. Alamos Intermediate School Covered Lunch Shelter Energy Profile

3.4.4 Boys Republic

Situated in rural Chino Hills, this site is an example of the ETS initial efforts to incorporate PV sites into a the community where no PVs currently exist. This system was designed to be an integral part of the students' everyday life (Figure 23). The PV array is situated directly above the living quarters in the center of the campus, allowing for maximum exposure to students and visitors. The energy generated by this system offsets the energy consumption for the entire dormitory on which it is mounted.



Figure 23. Boys Republic Roof-Mounted System

The system consists of 126 Siemens SP-75 Modules, rated at 9.5 kW STC. Power conditioning is accomplished by the use of two 5 kW Omnion Series 2400 Inverters. Production and environmental data are collected in 15-minute increments by an automatic Data Acquisition System. Table 13 summarizes the technical characteristics of this facility.

Table 13. Boys Republic System Description

Location: Chino Hills, California			
Array Size:	9.5 kW	Annual Energy Projection:	16,029
Panel Manufacturer:	Siemens SP-75	Number of Modules:	126
Inverter Manufacturer:	Omnion (Qty. 2)	Model:	5 kW Series 2400
DAS Manufacturer:	Campbell Scientific	Model:	CR10X

Figure 24 illustrates this site's average monthly energy production.

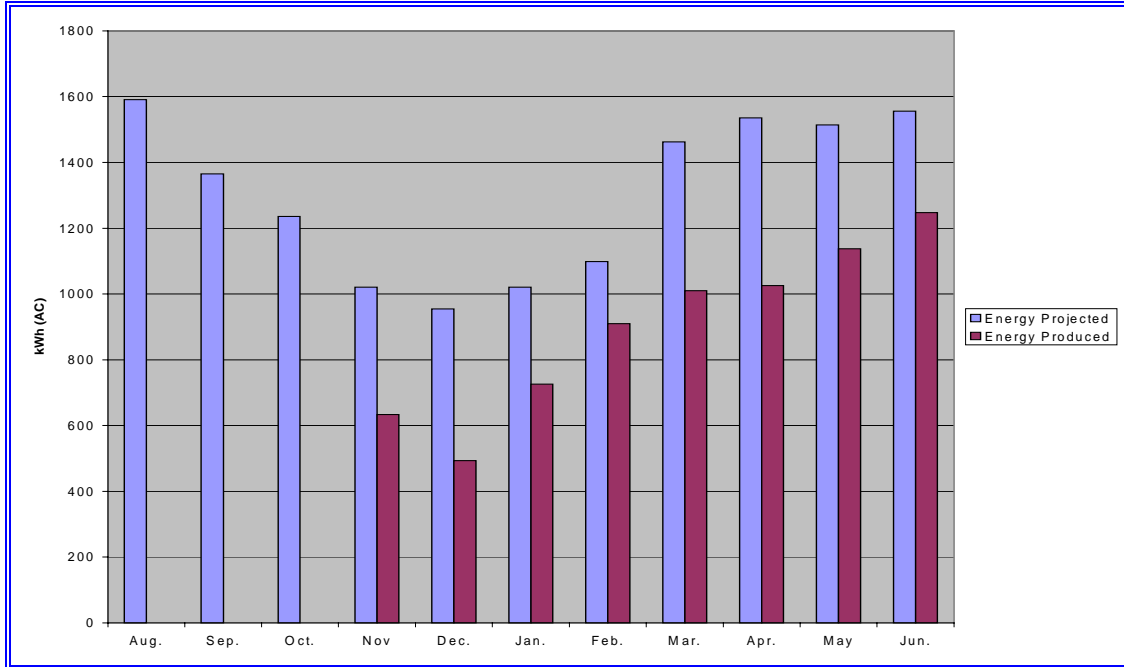


Figure 24. Boys Republic Roof-Mounted System Energy Profile

4.0 Lessons Learned

4.1 Marketing Lessons Learned

4.1.1 Subsidy Continuation

The goal of reducing PV materials costs by raising market demand to production levels that support economies of scale, continues to be valid. The success of this effort is dependent upon the expanded deployment of small to medium-sized commercial and residential units. However, penetration of this market segment will continue to require direct and indirect subsidies for the foreseeable future. This was clearly evidenced during the site selection process where a significant number of host sites were not interested in displaying and promoting a PV system until they were informed of the subsidies available for such a system.

4.1.2 Commercialization Potential

Significant cost reductions can be realized through standardization of material and installation procedures. Significant mass commercial deployment, standardization of products, and consistent methodology in program management are critical success factors in reducing the installed cost of PVs. As the industry matures, the source of subsidies should be the industrial entities that will ultimately benefit from expansion of the PV marketplace.

Full commercialization of standard, yet modular, designs offers a significant growth opportunity that is presently untapped. The standardized systems installed by ETS were not replicated during the course of this project. Future installations where no custom system design costs will be incurred and where volume production is in effect will significantly reduce the costs of such system.

4.1.3 Benefit to California

This project supports the PIER program objective of improving the reliability/quality of California's electricity because PV offers an environmentally benign alternative to distributed electrical generation. Grid support systems such as the Huntington Library and Monterey Hills Elementary School eliminated the need for localized peaking generators and improved the reliability of an aging distribution system. Secondly, the clean electrical energy produced offset the emission of approximately 201 pounds of NO_x and 78 tons of CO₂ that would have resulted from generation of an equivalent amount of energy by conventional generation methods.

4.1.4 User Friendliness

Realistically, the installations best suited for the residential and small commercial market segments previously described, must be low maintenance as well as customer friendly. Grid-connected systems will require pre-operational inspection and certification, some regular professional maintenance, and provisions for emergency maintenance response. However, the systems installed under this project required very little maintenance and generated no emergency response situations. ETS anticipates that future user-installed systems will also require very little, or no regular maintenance.

4.1.5 Promotion and Educational Issues

It is necessary to continue industry efforts to popularize the use of energy generated from renewable sources. The most successful appeals will be to niche markets that can afford to choose the more expensive PV alternative over fossil fuel generation strategies that enjoy a current cost advantage.

The distribution of well-crafted printed materials in conjunction with high visibility sites is a solid approach to the promotion and popularization of PV system use. In addition, the development of PV text materials, for use by educators in the preparation of primary and secondary school curricula, will assist in the public acceptance of PV in the future. At many ETS educational sites, the faculty encouraged the use of solar projects at the science fairs and several schools participated in contests where the students designed their own solar energy systems. These efforts help us to educate the leaders of tomorrow about renewable energy and how such systems can raise our standard of living.

4.2 Design Lessons Learned

4.2.1 Site Selection Criteria

The basic specification of an ETS solar site requires review of both physical and political issues. To generate public support, physical characteristics such as available sunlight, shading, and irradiance must be considered, together with glare, view lines, and general site appearance. Without public support, many applications will not be politically feasible, as issues attendant to the permit acquisition process will add both time and cost to proposed projects.

Attention must be paid to the concerns of site owners, particularly the owner's perceptions of aesthetic acceptability. The objective of making PV applications visible as a method of encouraging market expansion must be balanced against the concerns of those who will see these facilities everyday. Wherever possible, balance of system components should be hidden from view at highly visible public sites. The development of flat roof and building integrated patio systems offers a low visibility solution for residential areas. If flat roofs are not available at a specific site, solar roof shingles offer an attractive alternative.

4.2.2 Standardization

This project developed two standard configurations for residential systems: an expandable roof shingle system and an expandable modular rooftop configuration that is appropriate for public and commercial use. Because these configurations require only basic construction skills, contractors and remodelers hiring common labors, do-it-yourselfers, weekend hobbyists, or handymen can easily install them. The ease of installation is expected to encourage market growth, increase demand, and drive unit prices down.

The use of standard PV systems will facilitate adoption and the integration of PV applications within new residential and commercial structures. Therefore, architects, building designers and site developers will gain confidence in the costs and benefits of these systems and become more knowledgeable regarding design requirements, i.e. structural, wind, and seismic loads.

Standardization will also simplify the materials procurement and installation procedures. The development of simple “plug-and-play” system components will have a substantial impact on construction time and, as a result, the installation costs for similar systems will be reduced.

4.2.3 Integration

The use of PV devices, integrated with building infrastructure materials reduced the overall construction costs of PVs. This project promoted the use of building-integrated materials and developed two standard packages that use these materials. The residential patio system incorporated a metal standing seam roof that had a PV laminate built into the top of each roof panel. This allowed for the PV panels to serve as the roofing material as well as an energy provider. Secondly, the PV roof shingle project at Cal Poly University, allowed for the displacement of composition roof shingles. Both of these systems are quite architecturally pleasing and are not obtrusive in any way.

4.2.4 Interconnection Standards

The development of uniform interconnection standards and consistent regulatory policies are vital to the future of PV. The viability of most residential and small commercial PV systems hinges upon the ability to connect to a utility power grid. Therefore, standards for hardware, connection, and inspection must be developed, published, and widely disseminated. Such standards will help local utilities accommodate their ratepayers who wish to generate their own clean, reliable source of electricity. Once such standards are in place, individual system inspection, acceptance, and safety concerns of the local power distribution company will be greatly eased.

As ETS worked with various utility companies to interconnect the PV systems, it was evident that these companies were not as comfortable as we thought in allowing our systems to be connected to their grid. Several issues such as anti-islanding and AC/DC disconnects were of significant interest to them-and rightly so. However, as new IEEE standards were released, and an easily replicable interconnection agreement was developed, the local utilities seem to better embrace the technology making it much easier to get our systems interconnected with the local distribution system.

4.3 Hardware Issues

In this project, the most troublesome component of any of the PV systems was the inverter. Significant work is needed to bring this component’s reliability and performance into equilibrium with the rest of the system components.

4.3.1 Trace SW5548 Inverter Capacity Issue

During routine inspections at two operational sites, U.C. Irvine and Glenmeade, ETS’ partner Solar Utility observed signs of excessive current flow in the conductor between the input capacitor and the DC input terminals of the Trace SW5548 inverters. The input capacitor is part of the circuit that regulates operational DC voltage for the inverter. Excessive current to the input terminals indicated that the capacitor was undersized. The problem was brought to the manufacturer (Trace)’s attention, and the manufacturer recommended the addition of a second parallel input capacitor to correct the problem.

Further research determined that the problem occurs with Trace SW5548 inverters when PV array output is near or equal to the inverter's maximum rated capacity. Solar Utility installed the modification at all sites using the inverter. Subsequent measurement and observation indicate that this fix has solved the problem. Solar Utility was the first to bring this problem to Trace's attention; however, Trace has not yet modified its standard grid-tied SW5548 inverter to include the second input capacitor. Because of Solar Utility's experience with power conversion technology, this problem was quickly diagnosed and corrected. As a result of this lesson learned, this fix will be incorporated by ETS as a standard specification for future systems.

4.3.2 Omnion Inverter Coolant Leak

Several of the Omnion Series 2400 inverters installed in conjunction with roof systems lost coolant as the result of leaks. This caused an over temperature condition that disconnected the inverter. The inverters are designed to operate within a prescribed temperature regime and when tolerances are exceeded, the devices cut off and power produced by the PV array is shunted to a bypass circuit and is disconnected from the systems load.

The early inverters in this series used a cooling fluid composed of water and a chemical coolant. Research by the manufacturer determined that a contaminating microbe, which ate holes into the aluminum heat exchanger, caused the leaks. The manufacturer replaced the defective units (under warranty) and modified their production techniques to eliminate the possibility of future microbial contamination.

4.3.3 Voltage Spike Protection – Omnion Series 2400

A fire developed in one inverter that appears to have been caused by damage to a varistor. The varistor is part of the inverter lightning surge protection system and apparently functioned as designed to isolate the array from the grid under excessive voltage (spike) conditions. However, it would seem that a disconnect should have occurred before fire conditions developed.

This apparent design weakness was reported to the manufacturer. ETS has not been informed of any corrective measures that have been taken or are planned.

4.4 Operational Lessons Learned

4.4.1 Economic Analysis

Assuming a 20-year useful life and real system energy outputs equivalent to 85 percent of projections, the value of energy produced over system life is \$869,872.

4.4.2 Energy Produced During Reporting Period

Based upon the performance data collected by the automated Data Acquisition System from over the last 12 months, the actual overall energy generated was approximately 85 to 90 percent of that projected by design calculations. This is evident by the comparison graphs shown in Sections 3.1.1 through 3.4.4.

4.4.2.1 Value of Energy Produced to System Owners

Based upon a weighted average retail cost of \$0.121508/kWh, the value of energy produced by installed systems during the reporting period is approximately \$51,032.21 (Table 14).

Table 14. Energy Value to Owners

Site Name	Energy Produced	Value (\$0.121508/kWh)
Monterey Hills	170,661.4	\$20,736.73
Huntington Library	112,212.8	\$13,634.75
Elizabeth Court	54,84.9	\$666.46
Standard Residential Patio Cover	8,37.8	\$101.80
Standard Residential Garage Mount	13,81.5	\$167.86
UCI Straw Bale House	12,83.9	\$156.00
Knott's Berry Farm	33,238.0	\$4,038.68
Santa Monica Pier	49,744.0	\$6,044.29
Glenmeade	13,556.1	\$1,647.17
UCI Solar Deck	12,643.0	\$1,536.23
Alamitos	11,764.0	\$1,429.42
Boys Republic	7,183.1	\$872.80
Totals	419,990.5	\$51,032.21

4.4.3 Environmental Benefit

4.4.3.1 Net Pollutant Offset

Because PV generates electricity directly from the sun, air pollutant emissions are not produced. If a comparable amount of electricity were produced by combustion of fossil fuels, approximately 201 pounds of NO_x and 78 tons of CO₂ would have been released to the atmosphere.

4.4.3.2 Value of Pollution Offset

All of the application sites covered by this report are located within the South Coast Air Quality Management District. It is the District's statutory responsibility to issue and enforce rules and regulations that protect air quality throughout the South Coast Air Basin. The agency also supervises a Regional Clean Air Incentives Market (RECLAIM) that facilitates the transfer of pollutant emission allowances among existing and future stationary sources.

The RECLAIM market places an economic value on the right for stationary source owners to emit pollutants based upon a number of factors, including the schedule when such emissions will be permitted. In general, near-term credits (or allowances) are less valuable future credits. The current (1999 to 2000) RECLAIM transaction price for NO_x offset credit is \$2.179/pounds. Based upon the current transaction price, the value for pollutant emissions offset by applications covered within this report is \$437.98. Currently, the RECLAIM exchange does not have a market for CO₂ emission credits.

5.0 Conclusions

ETS operated and monitored several PV systems to evaluate their year-round efficiency in an effort to meet its purpose for doing the project as well as accomplish the project objectives, as detailed below.

5.1 Purpose of the Project

Learn how PV systems operate once installed in the field.

Learn how weather impacts the year-round operation of PV systems.

Provide the PV industry with operational data that they can use to make PV systems more reliable and cost effective.

5.2 Project Objectives

Evaluate system performance and efficiency as compared to expected results.

Evaluate the seasonal effects of year-round PV operations in California.

Provide written report findings for public dissemination.

Additionally, ETS was also able to accomplish the following program objectives:

- Demonstrate the value of PV as a distributed generation resource for grid support and local reliability.
- Develop standard small to medium-sized PV system configurations.
- Increase public awareness and community acceptance of PVs by placing systems in high-profile sites, creating and distributing public information materials, and coordinating the incorporation of PV information within the science curriculum at participating schools.
- Improve the performance and reliability of PV systems and components by testing and monitoring PV equipment in the field and working with manufacturers to solve critical operational problems.

5.3 Project Outcomes

In regard to the proposed purpose and objectives set forth above, the project resulted in the following outcomes:

- ETS tested and monitored PV equipment at 12 field sites. The actual energy generated was approximately 85 percent of that projected by design calculations.
- ETS found that overall, the PV systems operated as projected with increased energy production in the summer and lower energy production during the winter. However, other seasonal parameters such as cell and ambient temperature did in fact have a more significant than expected affect on the panels as evidenced by the lower overall energy production levels. Several of the sites also experienced severe soiling which reduced the amount of energy the PV system produced.
- The Monterey Hills Elementary School and Huntington Library applications demonstrate the value of PV as a distributed generation resource for grid

support and local reliability. Since these projects have been operational, there have been no brown-outs, no voltage flickering during peak usage, and no complaints from any of the residents regarding the quality of power they have received.

- ETS developed standard configurations for residential systems and one expandable modular rooftop configuration that is appropriate for public and commercial use. The ease of installation of these systems is expected to encourage market growth, increase demand, and drive unit prices down. These standard design packages will simplify the materials procurement and installation process. By reducing construction time, it will reduce the installation costs of similar future systems.
- ETS developed small and medium-sized PV systems at multiple sites that have allowed for the standard design configurations to be replicable thereby reducing the design and installation costs. These systems included using off-the-shelf, widely available products allowing the do-it-yourselfer to install such standardized systems themselves.
- ETS increased public awareness and community acceptance of PVs by placing systems in high-profile sites such as Knott's Berry Farm and the Santa Monica Pier. ETS also promoted visibility and exposure to PV technology by incorporating PV systems at various educational sites.
- ETS and its partner, Solar Utility, provided performance feedback to inverter manufacturers resulting in timely diagnosis of problems and correction of manufacturing defects.

In summation, the technical and economic outcomes of this project were within an acceptable range of ± 15 percent and the demonstration sites selected by ETS clearly helped advance the public awareness and acceptance of PVs. By exceeding the original stated objectives of this project, the California Energy Commission, along with Edison Technology Solutions have assisted in the advancement of the PV commercialization efforts here in California.

5.4 Project Conclusions

- The technical and economic outcomes of this project showed that properly designed and situated PV systems, including conventional tilted-array, flat-panel, and building-integrated designs, were shown to operate within an acceptable range of ± 15 percent of their expected efficiency specifications.
- PV systems evaluated under a full range of seasonal variations, operated as projected with increased energy production in the summer and lower energy production during the winter. Longer daylight hours in the summer time increased overall energy production, more than offsetting decreased panel efficiency occasioned by top daytime temperatures. Cell and ambient temperature did in fact have a more significant than expected affect on the panels as evidenced by the lower overall energy production levels. Several sites also experienced severe soiling which reduced the amount of energy the PV system produced.

- ETS provided the PV industry with operational data that they can use to make PV systems more reliable and cost effective, by alerting manufacturers that the inverter was the most troublesome component of other PV systems.
- Of all sites, the Monterey Hills Elementary School and Huntington Library applications best demonstrated that PV is a valuable distributed generation resource for grid support and high-quality local reliability.
- ETS developed small and medium-sized PV systems at multiple sites using off-the-shelf, widely available products. Standard design packages will simplify the materials procurement, reducing the construction time and installation costs of similar future systems. The ease of installation of these standard design configuration systems is expected to encourage market growth, increase demand, and drive unit prices down.
- Demonstration sites selected by ETS to promote visibility and exposure to PV technology, clearly helped advance the public awareness and acceptance of PVs.

By exceeding the original stated objectives of this project, the California Energy Commission, along with Edison Technology Solutions have assisted in the advancement of the PV commercialization efforts here in California. The total cost of this project was \$2,427,000. The California Energy Commission portion of project cost was \$1 million. Cost sharing funds in the amount of \$1,427,000 were provided by participating agency and industry partners (Table 1).

Appendix I
Site Power Production Data

Summary Report Period: June 1,1999 to June 30,1999

System Information

Site: Alamitos Intermediate School
 Location: Garden Grove, CA
 System: 11.0 kW (PTC Rated), 1-Ø, 240 VAC
 Monitoring
 Start Date: September 4, 1998

DAS Uptime

Days of Reliable Data: 30 of 30 100.00%

Peak Parameters

Output Power (kW)	7.8	@ 1042 W/m ²	June 04, 1999 at 12:45 PM
Solar Irradiance (Watts/m ²)	1084.0	@ 7.67 kW	June 21, 1999 at 12:45 PM
Solar Panel Temperature (°F)	103.7	@ 7.01 kW	June 11, 1999 at 01:15 PM
Ambient Temperature (°F)	93.6	@ 6.224 kW	June 14, 1999 at 03:00 PM

Data Summary

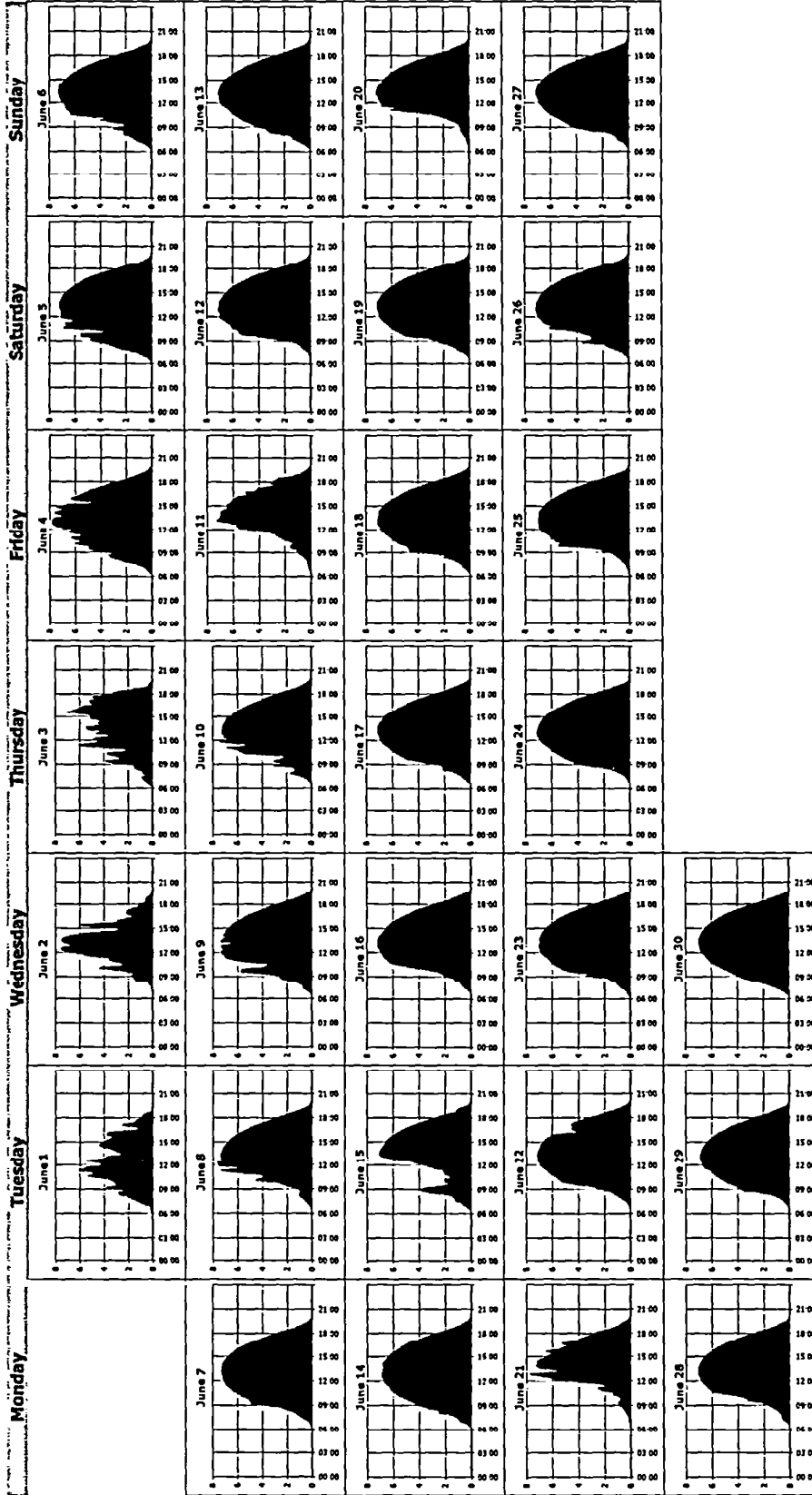
Total Monthly Energy Produced	1,577.1	kWh
Average Daily Energy Produced	52.6	kWh
Cumulative (since monitoring start date)	11,764.3	kWh
Average System Efficiency	7.24	%
Average Capacity Factor	19.91	%
Average Availability	55.21	%

Attached Charts

- Daily Energy Production
- Peak Output Power and Solar Irradiance
- Output Power vs. Solar Irradiance Linear Regression
- System Efficiency vs. Output Power
- Output Power vs. Solar Panel Temperature
- Capacity Factor and Availability

Error List

Date	Description	Resolution
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Summary Report Period: June 1,1999 to June 30,1999

System Information

Site: Bahm Residence
Location: Chino Hills, California
System: 2.40 kW (PTC Rated), 1-Ø, 2-wire, 240 VAC
Monitoring
Start Date: January 8, 1999

DAS Uptime

Days of Reliable Data: 30 of 30 100.00%

Peak Parameters

Output Power (kW)	1.688	@	1081 W/m ²	June 03, 1999	at	12:30 PM
Solar Irradiance (Watts/m ²)	1081	@	1.688 kW	June 03, 1999	at	12:30 PM
Solar Panel Temperature (°F)	142.9	@	1.296 kW	June 30, 1999	at	11:45 AM
Ambient Temperature (°F)	97.5	@	1.136 kW	June 14, 1999	at	03:30 PM

Data Summary

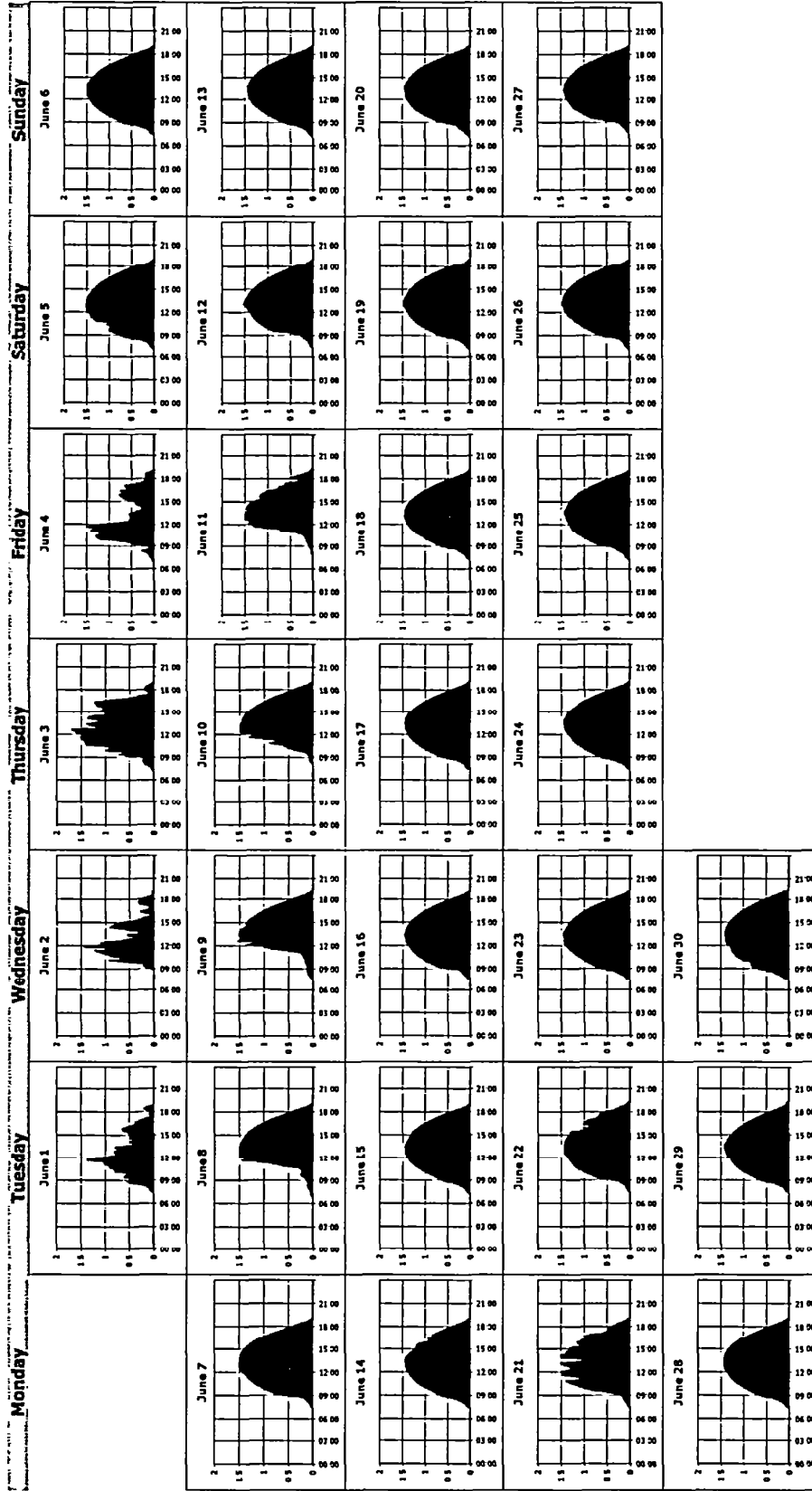
Total Monthly Energy Produced	300.2	kWh
Average Daily Energy Produced	10.0	kWh
Cumulative (since monitoring start date)	1,381.5	kWh
Average System Efficiency	7.40	%
Average Capacity Factor	17.37	%
Average Availability	48.02	%

Attached Charts

- Daily Energy Production
- Peak Output Power and Solar Irradiance
- Output Power vs. Solar Irradiance Linear Regression
- System Efficiency vs. Output Power
- Output Power vs. Solar Panel Temperature
- Capacity Factor and Availability

Error List

Date	Description	Resolution
	Abnormally low solar irradiance readings were measured this month; may be a defective pyranometer.	Paragon to replace pyranometer.



Summary Report Period: June 1,1999 to June 30,1999

System Information

Site: Boys Republic
Location: Chino Hills, California
System: 8.105 kW (PTC Rated), 1-Ø, 3-wire, 120/208 VAC
Monitoring
Start Date: September 24, 1998

DAS Uptime

Days of Reliable Data: 30 of 30 100.00%

Peak Parameters

Output Power (kW)	6.808 @ 1026 W/m ²	June 03, 1999 at 12:00 PM
Solar Irradiance (Watts/m ²)	1031 @ 6.186 kW	June 21, 1999 at 12:00 PM
Solar Panel Temperature (°F)	137.8 @ 5.633 kW	June 24, 1999 at 11:45 AM
Ambient Temperature (°F)	97.3 @ 4.694 kW	June 14, 1999 at 02:30 PM
Wind Speed (m/s)	2.498 @ 0.127 kW	June 17, 1999 at 07:15 PM

Data Summary

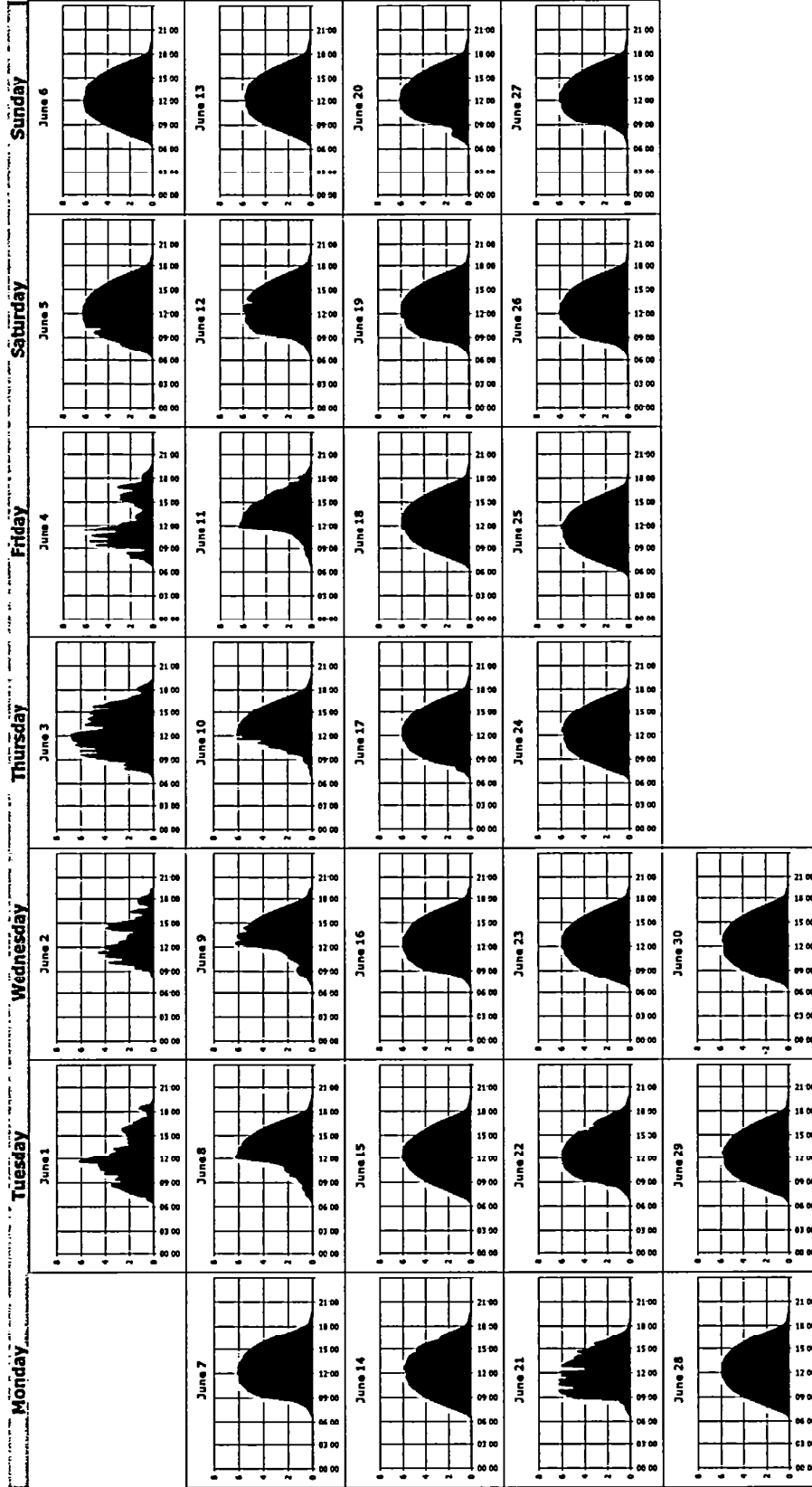
Total Monthly Energy Produced	1,247.6 kWh
Average Daily Energy Produced	41.6 kWh
Cumulative (since monitoring start date)	7,183.1 kWh
Average System Efficiency	8.71 %
Average Capacity Factor	21.38 %
Average Availability	54.20 %

Attached Charts

- Daily Energy Production
- Peak Output Power and Solar Irradiance
- Output Power vs. Solar Irradiance Linear Regression
- System Efficiency vs. Output Power
- Output Power vs. Solar Panel Temperature
- Capacity Factor and Availability

Error List

Date	Description	Resolution
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June 1999 Summary Report

System Information

Site: California State Polytechnic University, Pomona Hybrid Wind Turbine/PV Array
 Location: Pomona, California
 System: PV - 0.800 kW | Wind - 1.50 kW, 1-Ø, 3W, 120/240 VAC
 Monitoring
 Start Date: January 12, 1999

DAS Uptime

Days of Reliable Data: 30 of 30 100.00%

Peak Parameters

PV Array Output Power (kW)	0.724 @ 943 W/m ²	June 03, 1999 at 12:30 PM
Wind Turbine Output Power (kW)	0.190 @ 4.95 m/s	June 03, 1999 at 03:00 PM
Solar Irradiance (Watts/m ²)	1014 @ 0.704 kW	June 10, 1999 at 12:00 PM
Solar Panel Temperature (°F)	144.0	June 14, 1999 at 01:45 PM
Ambient Temperature (°F)	95.4	June 14, 1999 at 03:30 PM
Wind Speed (m/s)	5.015	June 03, 1999 at 12:30 PM

Data Summary

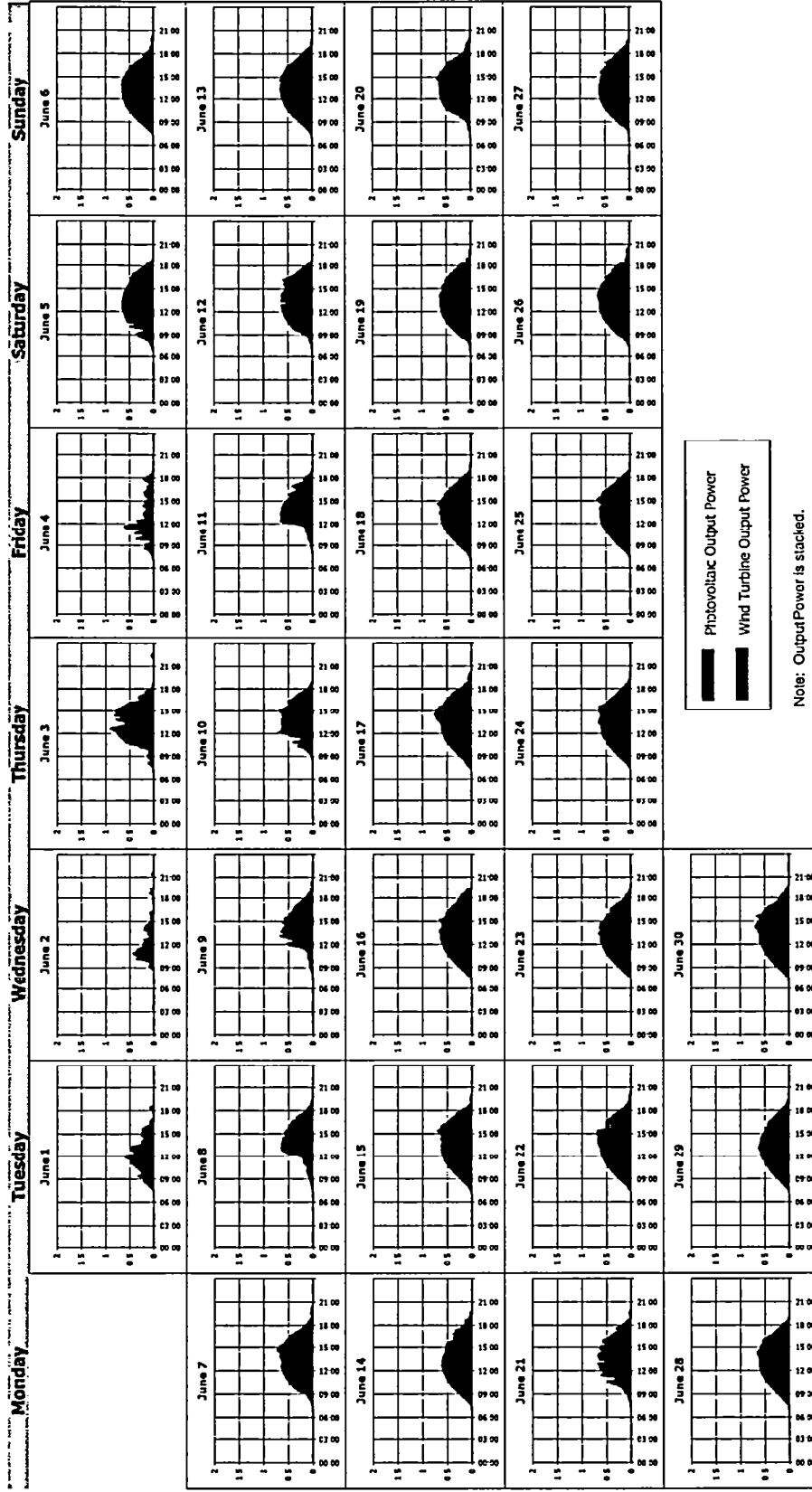
Total Monthly Energy Produced	130.0 kWh
Photovoltaic Array Energy Produced	120.9 kWh
Wind Turbine Energy Produced	9.15 kWh
Average Daily Energy Produced	4.33 kWh
Cumulative (since monitoring start date)	591.9 kWh
Average PV Array Efficiency	4.35 %
Average PV Capacity Factor	20.98 %
Average PV Availability	54.55 %
Average Wind Turbine Capacity Factor	0.85 %
Average Wind Turbine Availability	30.00 %

Attached Charts

- Daily Energy Production
- PV Array Peak Output Power and Peak Solar Irradiance
- PV Array Output Power vs. Solar Irradiance
- PV Array Efficiency vs. Output Power
- PV Array Output Power vs. Solar Panel Temperature
- Wind Turbine Peak Output Power and Peak Wind Speed
- Wind Turbine Output Power vs. Wind Speed
- Capacity Factor and Availability

Error List

Date	Description	Resolution
6/99	Ambient Temperature (AT) readings for June 1999 were corrupt; overflow values detected.	AT readings from the nearby Strawhouse site were used to replace the corrupt data.



Summary Report Period: June 1,1999 to June 30,1999

System Information

Site: Cal Poly Pomona Strawhouse
 Location: Pomona, California
 System: 1.60 kW (PTC Rated), 1-Ø, 3W, 120 VAC
 Monitoring
 Start Date: December 23, 1998

DAS Uptime

Days of Reliable Data: 30 of 30 100.00%

Peak Parameters

Output Power (kW)	1.520 @ 948 W/m ²	June 03, 1999 at 12:30 PM
Solar Irradiance (Watts/m ²)	980 @ 1.432 kW	June 10, 1999 at 12:00 PM
Solar Panel Temperature (°F)	156.3 @ 1.216 kW	June 14, 1999 at 03:00 PM
Ambient Temperature (°F)	95.4 @ 1.096 kW	June 14, 1999 at 03:30 PM
Wind Speed (m/s)	4.765 @ 1.52 kW	June 03, 1999 at 12:30 PM

Data Summary

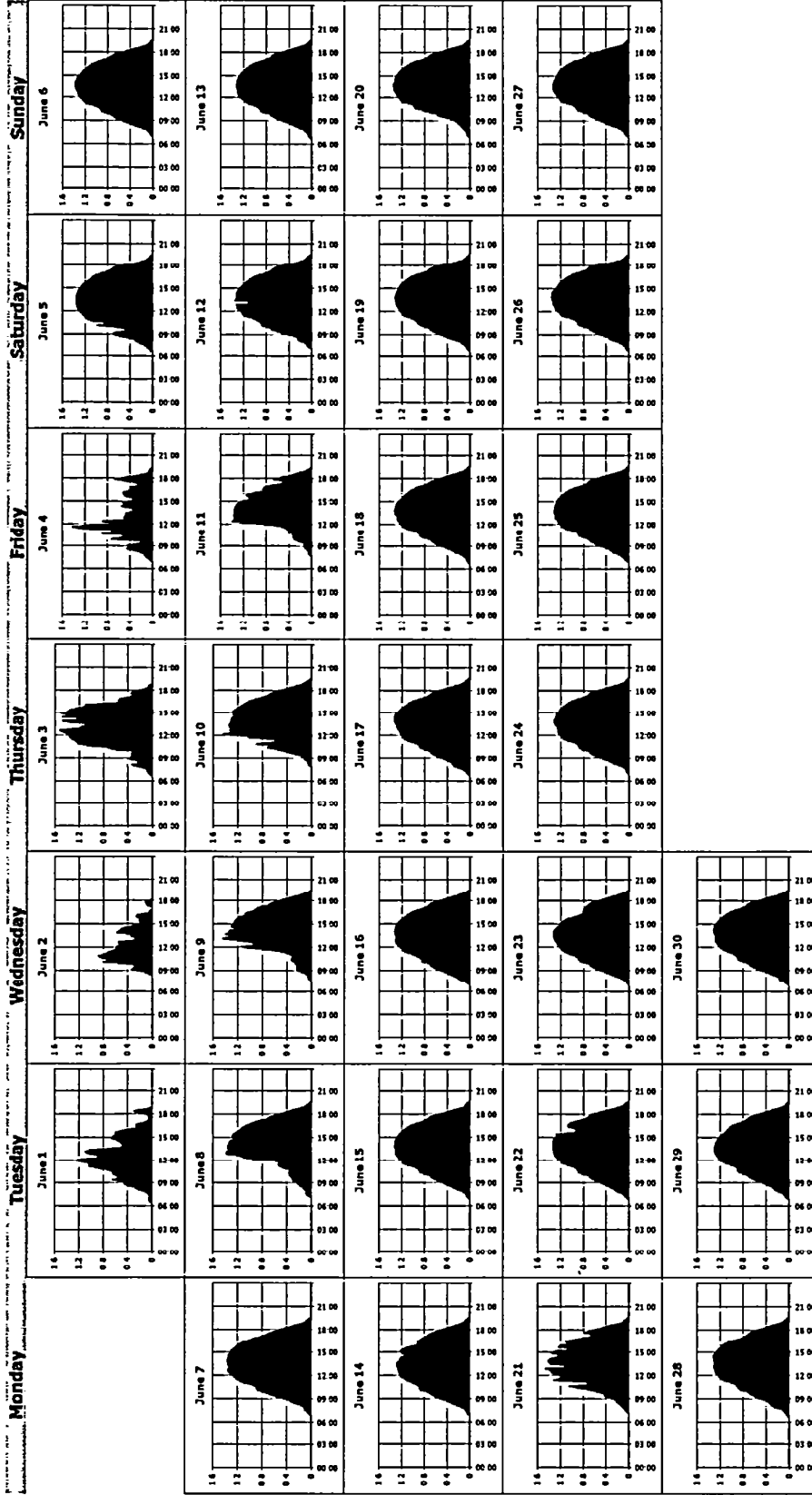
Total Monthly Energy Produced	281.3 kWh
Average Daily Energy Produced	9.38 kWh
Cumulative (since monitoring start date)	1,283.9 kWh
Average System Efficiency	5.89 %
Average Capacity Factor	24.41 %
Average Availability	51.15 %

Attached Charts

- Daily Energy Production
- Peak Output Power and Solar Irradiance
- Output Power vs. Solar Irradiance Linear Regression
- System Efficiency vs. Output Power
- Output Power vs. Solar Panel Temperature
- Capacity Factor and Availability

Error List

Date	Description	Resolution
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June 1999 Summary Report

System Information

Site: Cal Poly Pomona Tracker
Location: Pomona, California
System: One 12.8 kW Circuit, 3-Ø, 120/208 VAC Concentrator
Monitoring
Start Date: July 1, 1998

DAS Uptime

Days of Reliable Data: 30 of 30 100.00%

Peak Parameters

Output Power (kW)	9.61 @ 1068 W/m ²	June 03, 1999 at 12:30 PM
Solar Irradiance (Watts/m ²)	1206 @ 8.33 kW	June 04, 1999 at 11:30 AM
Direct Normal Irradiance (W/m ²)	832 @ 8.37 kW	June 26, 1999 at 02:00 PM
Solar Panel Temperature (°F)	130.8 @ 8.2 kW	June 24, 1999 at 10:30 AM
Ambient Temperature (°F)	99.7 @ 8.2 kW	June 15, 1999 at 03:00 PM

Data Summary

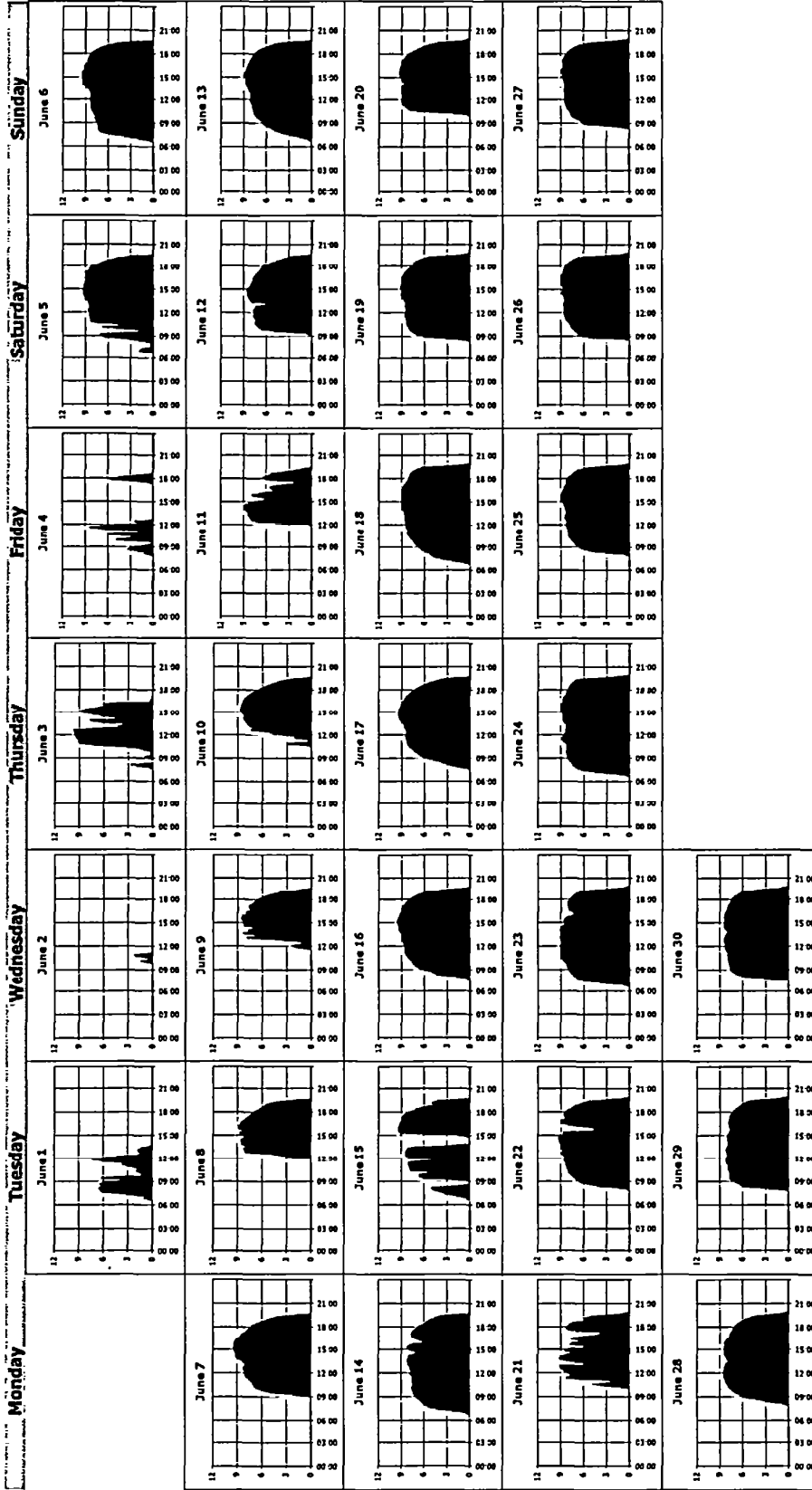
Total Monthly Energy Produced	2,161.3 kWh
Average Daily Energy Produced	72.0 kWh
Cumulative (since monitoring start date)	18,887.4 kWh
System Efficiency	12.93 %
Average Capacity Factor	23.45 %
Average Availability	43.16 %

Attached Charts

- Daily Energy Production
- Peak Output Power and Solar Irradiance
- Output Power vs. Solar Irradiance Linear Regression
- System Efficiency vs. Output Power
- Output Power vs. Solar Panel Temperature
- Capacity Factor and Availability

Notes

1. Concentrator efficiency (%) = Output power (Watts) / [DNI (W/m²) * surface area (m²)]
2. Direct Normal Irradiance (DNI) measured by pyraheliometer installed mid-June



Summary Report Period: June 1,1999 to June 30,1999

System Information

Site: Elizabeth Court
Location: Cudahy, California
System: 7.2 kW (PTC Rated), 1-Ø, 3-wire, 120/240 VAC
Monitoring
Start Date: November 25, 1998

DAS Uptime

Days of Reliable Data: 30 of 30 100.00%

Peak Parameters

Output Power (kW)	5.232 @ 986 W/m ²	June 04, 1999 at 02:00 PM
Solar Irradiance (Watts/m ²)	988 @ 5.136 kW	June 04, 1999 at 11:30 AM
Solar Panel Temperature (°F)	86.4 @ 4.48 kW	June 19, 1999 at 12:30 PM
Ambient Temperature (°F)	92.6 @ 3.312 kW	June 14, 1999 at 04:00 PM
Wind Speed (m/s)	3.938 @ 0 kW	June 03, 1999 at 09:00 PM

Data Summary

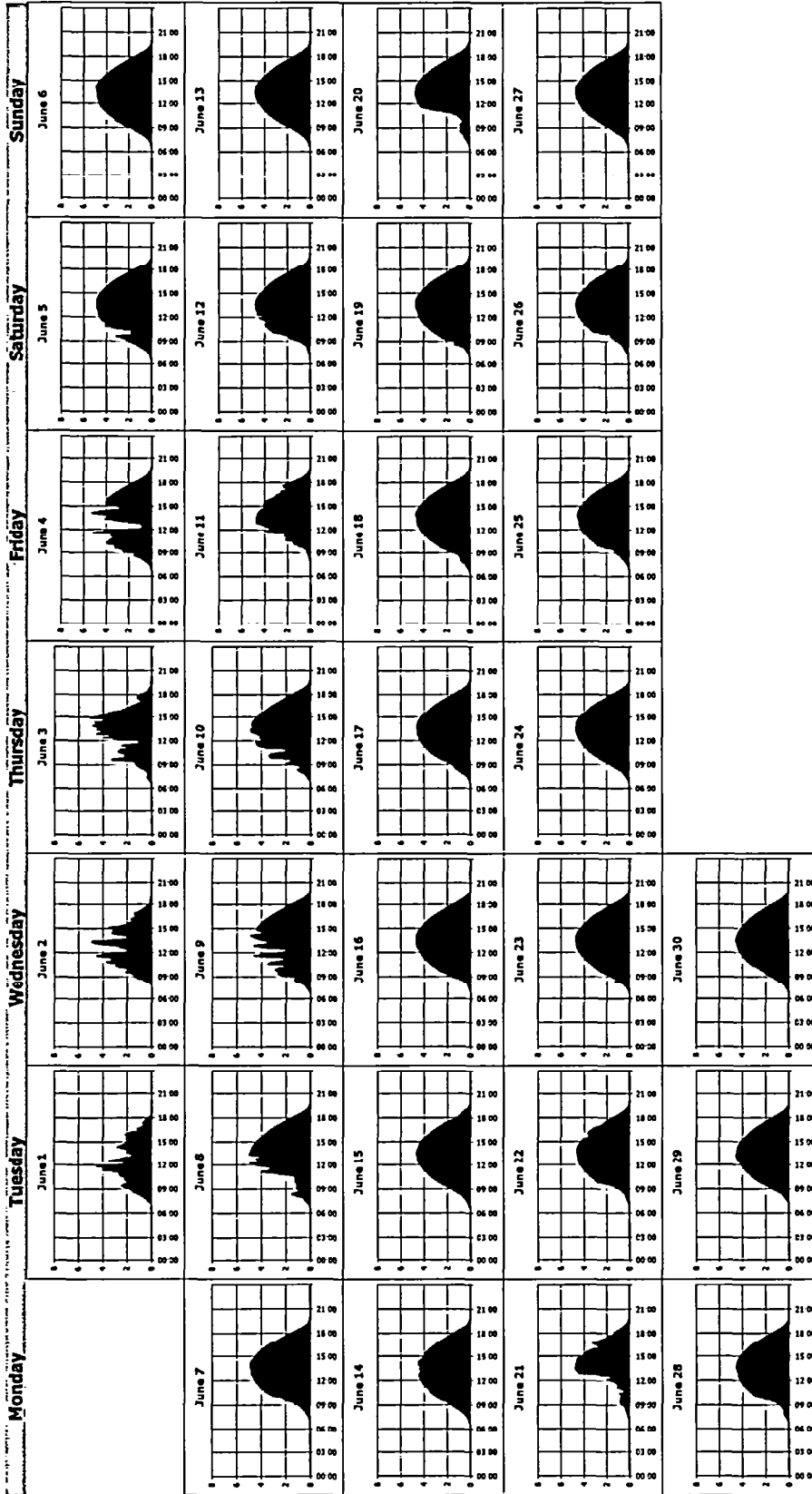
Total Monthly Energy Produced	960.3 kWh
Average Daily Energy Produced	32.0 kWh
Cumulative (since monitoring start date)	5,484.9 kWh
Average System Efficiency	9.15 %
Average Capacity Factor	18.52 %
Average Availability	52.92 %

Attached Charts

- Daily Energy Production
- Peak Output Power and Solar Irradiance
- Output Power vs. Solar Irradiance Linear Regression
- System Efficiency vs. Output Power
- Output Power vs. Solar Panel Temperature
- Capacity Factor and Availability

Error List

Date	Description	Resolution
	Solar panel temp readings are lower than expected.	



Summary Report Period: June 1,1999 to June 30,1999

System Information

Site: Glenmeade Elementary School
Location: Chino Hills, California
System: 10.6 kW (PTC Rated), split-Ø,120/208 VAC, 4 WY
Monitoring
Start Date: August 13, 1998

DAS Uptime

Days of Reliable Data: 30 of 30 100.00%

Peak Parameters

Output Power (kW)	9.61	@ 989 W/m ²	June 03, 1999 at 12:15 PM
Solar Irradiance (Watts/m ²)	1063	@ 8.81 kW	June 03, 1999 at 12:30 PM
Solar Panel Temperature (°F)	131.1	@ 8.26 kW	June 24, 1999 at 11:30 AM
Ambient Temperature (°F)	103.7	@ 7.76 kW	June 14, 1999 at 03:15 PM

Data Summary

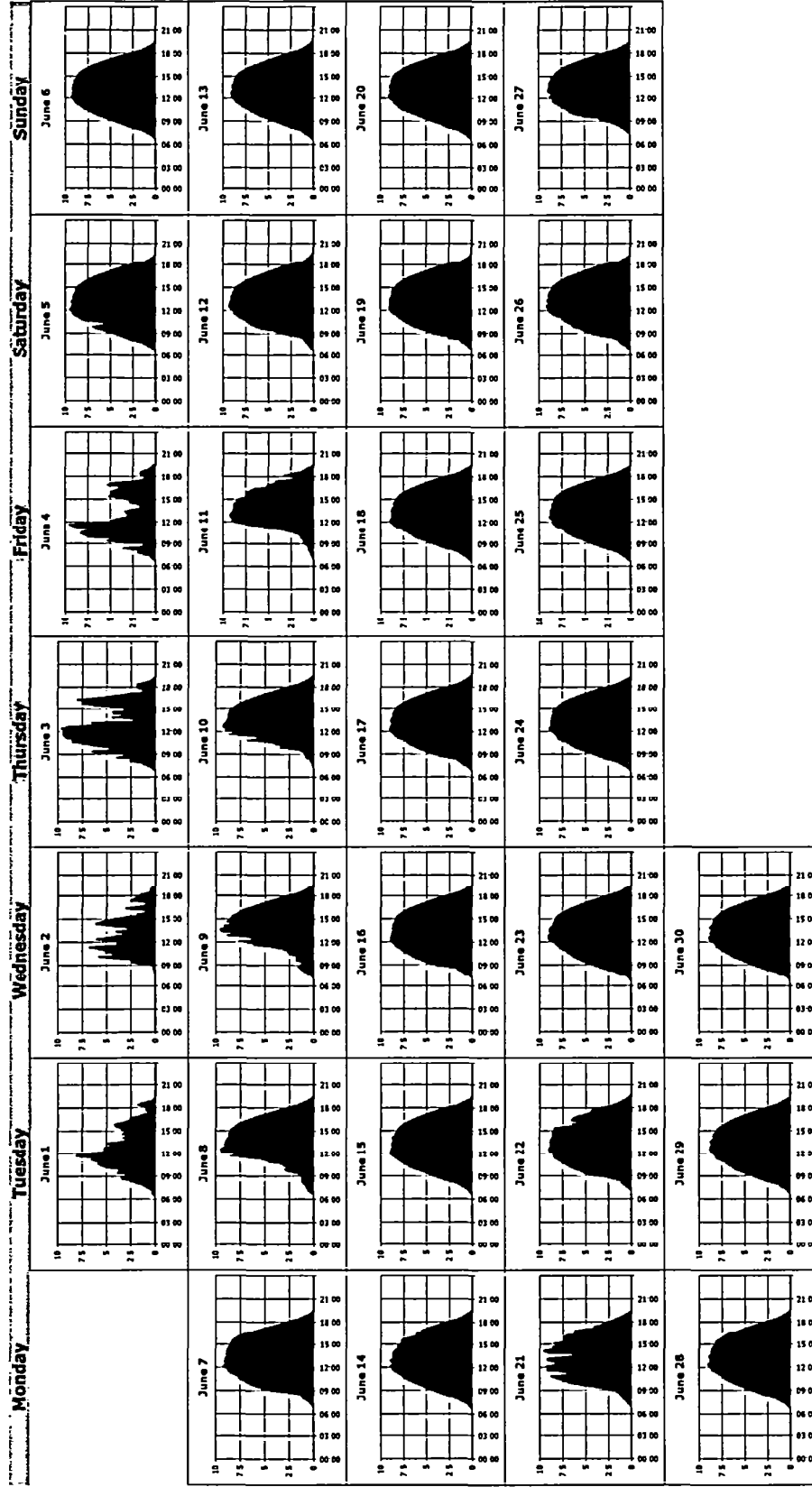
Total Monthly Energy Produced	1,944.7	kWh
Average Daily Energy Produced	64.8	kWh
Cumulative (since monitoring start date)	13,556.1	kWh
Average System Efficiency	6.08	%
Average Capacity Factor	25.48	%
Average Availability	52.26	%

Attached Charts

- Daily Energy Production
- Peak Output Power and Solar Irradiance
- Output Power vs. Solar Irradiance Linear Regression
- System Efficiency vs. Output Power
- Output Power vs. Solar Panel Temperature
- Capacity Factor and Availability

Error List

Date	Description	Resolution
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Summary Report Period: June 1,1999 to June 30,1999

System Information

Site: Huntington Library
 Location: San Marino, California
 System: 65.5 kW (STC Rating), 3-Ø, 120/208 VAC, 4WY
 Monitoring
 Start Date: November 1, 1997

DAS Uptime

Days of Reliable Data: 30 of 30 100.00%

Peak Parameters

Output Power (kW)	53.6 @ 919 W/m ²	June 07, 1999 at 03:15 PM
Solar Irradiance (Watts/m ²)	954 @ 51.6 kW	June 21, 1999 at 02:30 PM
Ambient Temperature (°F)	106.2 @ 48.8 kW	June 14, 1999 at 03:45 PM
Wind Speed (m/s)	1.884 @ 50 kW	June 10, 1999 at 02:30 PM

Data Summary

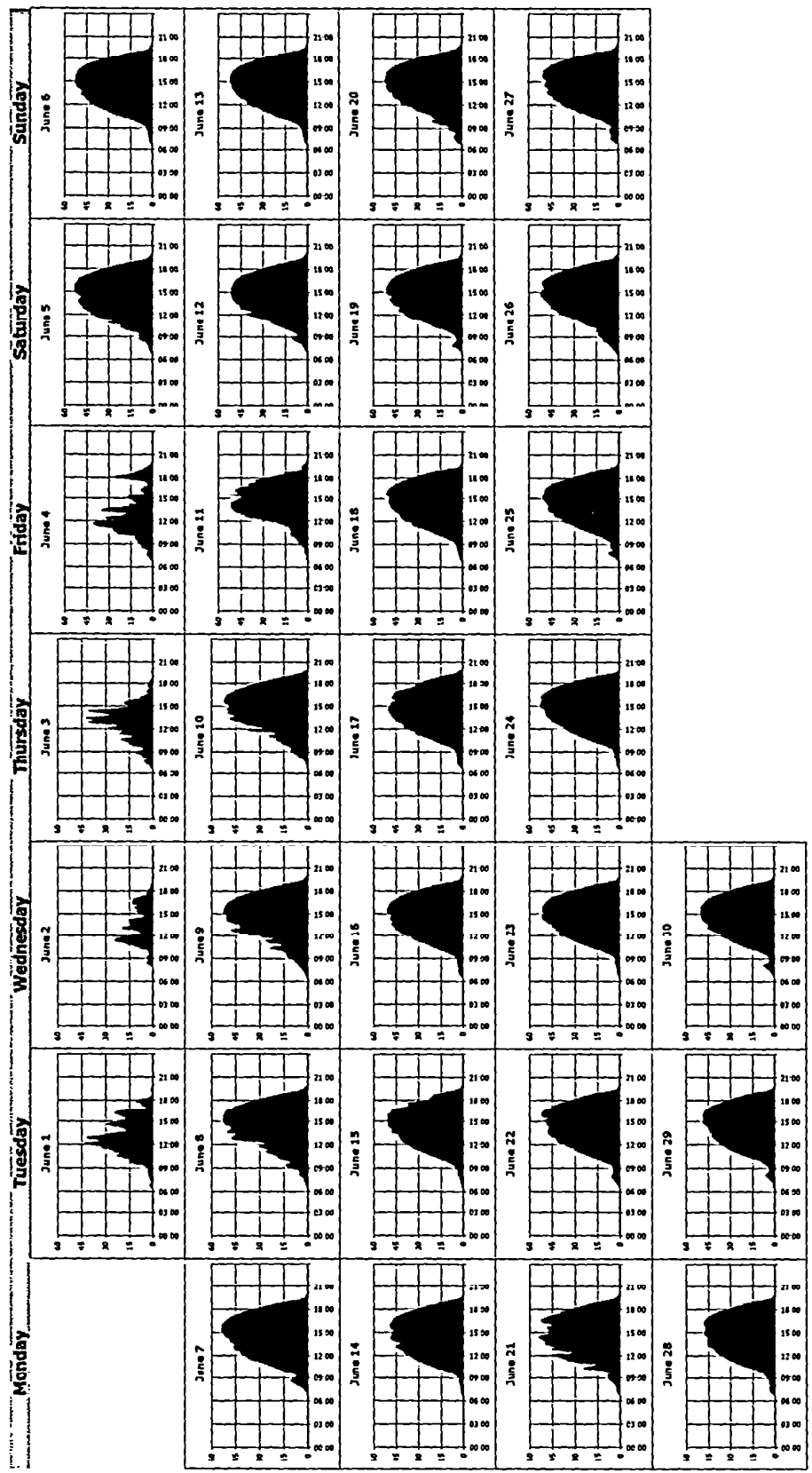
Total Monthly Energy Produced	9,907.9 kWh
Average Daily Energy Produced	330.3 kWh
Cumulative (since monitoring start date)	112,212.8 kWh
Average System Efficiency	6.58 %
Average Capacity Factor	21.01 %
Average Availability	54.69 %

Attached Charts

- Daily Energy Production
- Peak Output Power and Solar Irradiance
- Output Power vs. Solar Irradiance Linear Regression
- System Efficiency vs. Output Power
- Capacity Factor and Availability

Error List

Date	Description	Resolution
6/99	Due to corrupted Solar Panel Temperature readings for the entire month, Solar Panel Temperature analysis is not included with this report.	



Summary Report Period: June 1,1999 to June 30,1999

System Information

Site: Knotts Berry Farm
 Location: Anaheim, California
 System: 29.7 kW (PTC Rated), 3-Ø, 120/208 VAC, 4WY
 Monitoring
 Start Date: August 6, 1998

DAS Uptime

Days of Reliable Data: 30 of 30 100.00%

Peak Parameters

Output Power (kW)	26.4 @ 994 W/m ²	June 04, 1999 at 12:30 PM
Solar Irradiance (Watts/m ²)	1029 @ 24.39 kW	June 11, 1999 at 01:00 PM
Solar Panel Temperature (°F)	133.5 @ 22.61 kW	June 14, 1999 at 12:30 PM
Ambient Temperature (°F)	92.6 @ 21.11 kW	June 14, 1999 at 02:45 PM
Wind Speed (m/s)	3.499 @ 25.86 kW	June 04, 1999 at 01:15 PM

Data Summary

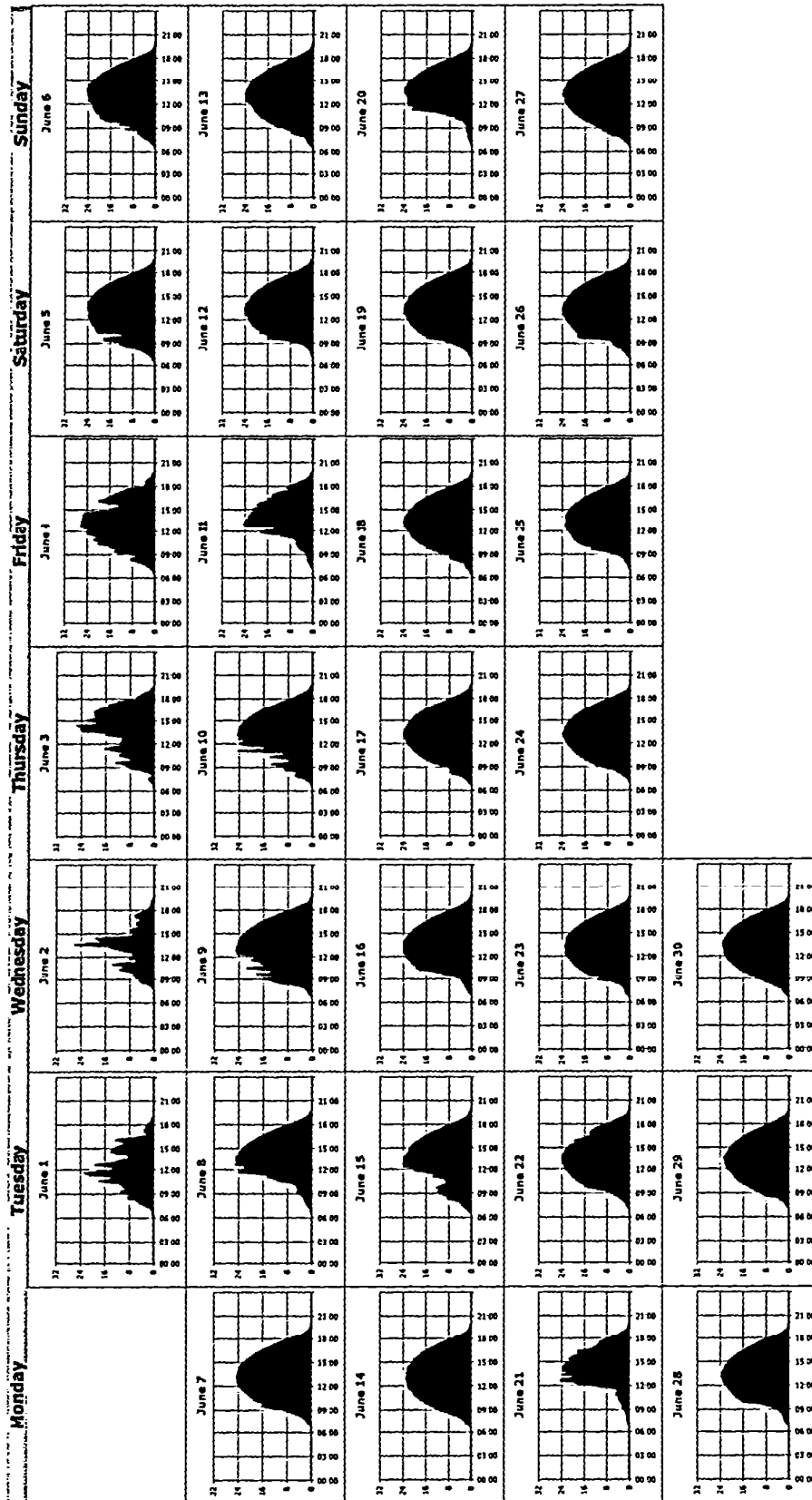
Total Monthly Energy Produced	5,032.1 kWh
Average Daily Energy Produced	167.7 kWh
Cumulative (since monitoring start date)	42,746.5 kWh
Average System Efficiency	8.47 %
Average Capacity Factor	23.53 %
Average Availability	92.71 %

Attached Charts

- Daily Energy Production
- Peak Output Power and Solar Irradiance
- Output Power vs. Solar Irradiance Linear Regression
- System Efficiency vs. Output Power
- Output Power vs. Solar Panel Temperature
- Capacity Factor and Availability

Notes

Date	Description	Resolution
6/99	High availability due to trace amounts of power produced throughout evenings (between 50 to 100 watts); may be attributed to outdoor lighting	



Summary Report Period: June 1,1999 to June 30,1999

System Information

Site: Krotzer Residence
Location: Monrovia, California
System: 2.0 kW (PTC Rated), 1-Ø, 2-wire, 240 VAC
Monitoring
Start Date: January 7, 1999

DAS Uptime

Days of Reliable Data: 30 of 30 100.00%

Peak Parameters

Output Power (kW)	1.848	@	1183 W/m ²	June 10, 1999	at	12:30 PM
Solar Irradiance (Watts/m ²)	1183	@	1.848 kW	June 10, 1999	at	12:30 PM
Solar Panel Temperature (°F)	141.7	@	1.552 kW	June 14, 1999	at	01:30 PM
Ambient Temperature (°F)	97.7	@	1.208 kW	June 14, 1999	at	03:45 PM
Wind Speed (m/s)	1.708	@	0.224 kW	June 29, 1999	at	05:00 PM

Data Summary

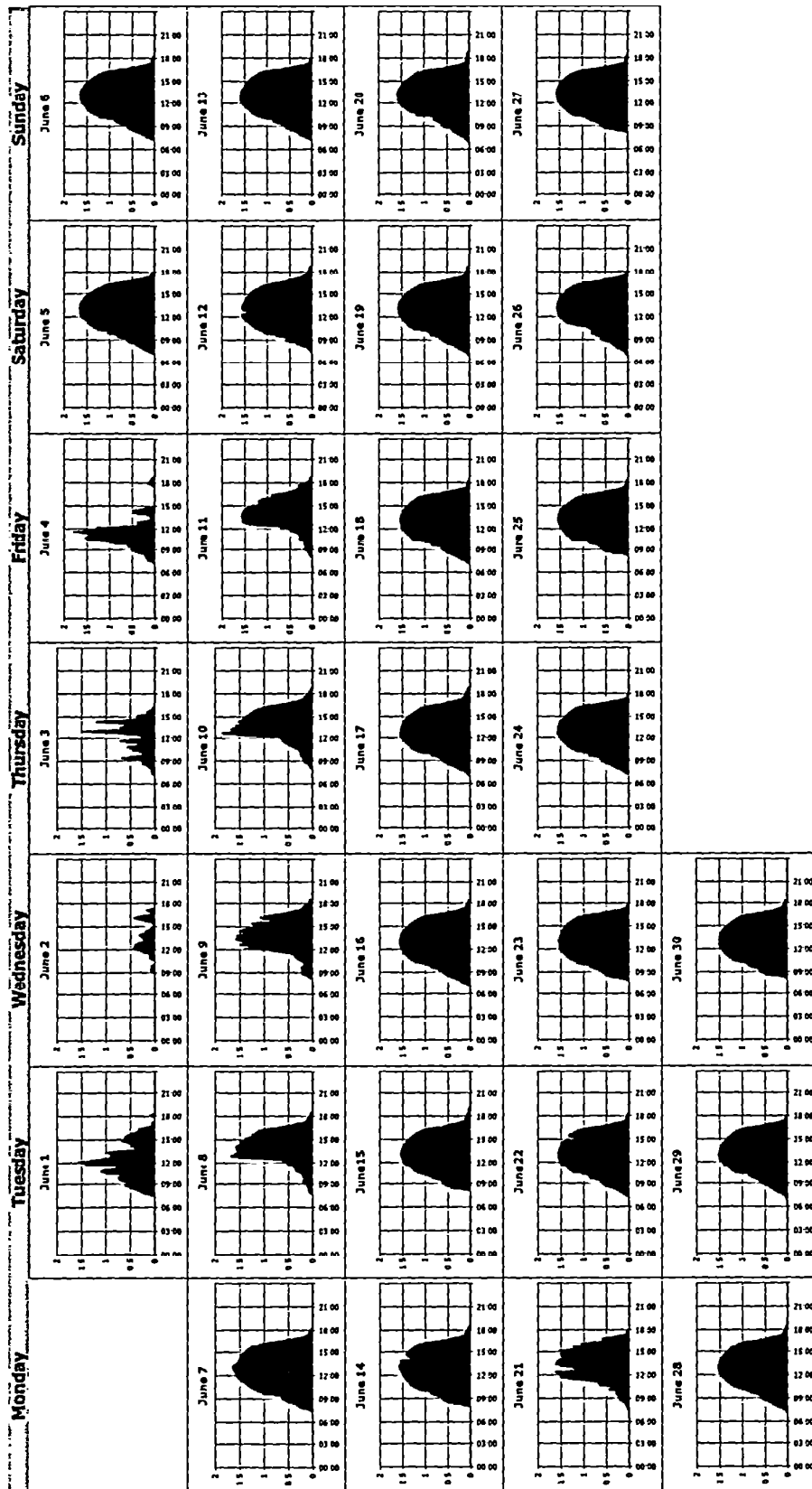
Total Monthly Energy Produced	278.1	kWh
Average Daily Energy Produced	9.27	kWh
Cumulative (since monitoring start date)	1,115.9	kWh
Average System Efficiency	3.73	%
Average Capacity Factor	19.31	%
Average Availability	43.92	%

Attached Charts

- Daily Energy Production
- Peak Output Power and Solar Irradiance
- Output Power vs. Solar Irradiance Linear Regression
- System Efficiency vs. Output Power
- Output Power vs. Solar Panel Temperature
- Capacity Factor and Availability

Error List

Date	Description	Resolution
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June 1999 Summary Report

System Information

Site: Monterey Hills Elementary School
 Location: South Pasadena, California
 System: One 100kW Circuit, 3-Ø, 277/408 VAC | One 12kW Circuit, split-Ø, 120/208 VAC
 Monitoring
 Start Date: November 1, 1997

DAS Uptime

Days of Reliable Data: 30 of 30 100.00%

Peak Parameters

Output Power 100kW Array (kW)	78.6 @ 1031 W/m ²	June 03, 1999 at 01:15 PM
Output Power 12kW Array (kW)	5.3 @ 1008 W/m ²	June 04, 1999 at 11:45 AM
Solar Irradiance (W/m ²)	1042.0 @ 73.9 kW	June 09, 1999 at 01:00 PM
Solar Irradiance (W/m ²)	1042.0 @ 5.174 kW	June 09, 1999 at 01:00 PM
Solar Panel Temperature (°F)	116.2	June 14, 1999 at 02:45 PM
Ambient Temperature (°F)	96.0	June 14, 1999 at 04:45 PM

Data Summary

Total Monthly Energy Produced	16,341.3 kWh
Average Daily Energy Produced (100kW Array)	511.7 kWh
Average Daily Energy Produced (12kW Array)	33.0 kWh
Cumulative (since monitoring start date)	170,661.4 kWh
Average Efficiency (100kW Array)	9.83 %
Average Efficiency (12kW Array)	4.42 %
Average Capacity Factor (100kW Array)	21.32 %
Average Availability (100kW Array)	56.84 %
Average Capacity Factor (12kW Array)	11.45 %
Average Availability (12kW Array)	48.96 %

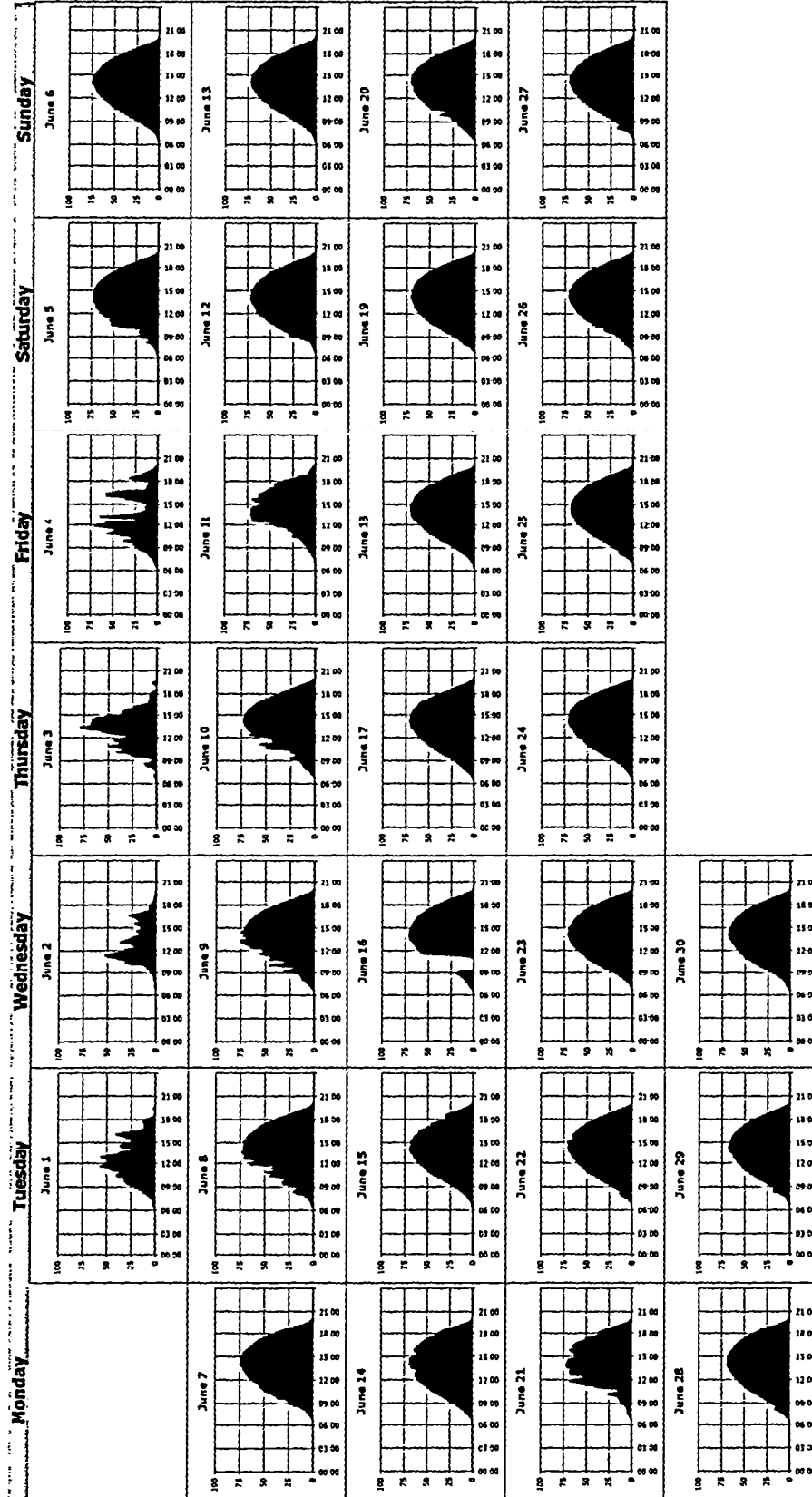
Attached Charts

- Daily Energy Production
- Peak Output Power and Solar Irradiance - 100 kW Array
- Peak Output Power and Solar Irradiance - 12 kW Array
- Output Power vs. Solar Irradiance Linear Regression - 100 kW Array
- Output Power vs. Solar Irradiance Linear Regression - 12 kW Array
- System Efficiency vs. Output Power - 100 kW Array
- System Efficiency vs. Output Power - 12 kW Array
- Output Power vs. Solar Panel Temperature - 100 kW Array
- Output Power vs. Solar Panel Temperature - 12 kW Array
- Capacity Factor and Availability for the 100 kW Array
- Capacity Factor and Availability for the 12 kW Array

Error List

Date	Description	Resolution
6/99	Low efficiency and output power from the 12kW Array is due to one of the inverters being offline the entire month.	Troubleshooting conducted at the site is recommended.

Power output on 100kW array off for part of the day.



Summary Report Period: June 1,1999 to June 30,1999

System Information

Site: Santa Monica Civic Auditorium
Location: Santa Monica, California
System: 31.0 kW (PTC Rated), 3-Ø, 480 VAC, 3-wire
Monitoring
Start Date: March 27, 1999

DAS Uptime

Days of Reliable Data: 30 of 30 100.00%

Peak Parameters

Output Power (kW)	26.6	@	1083 W/m ²	June 02, 1999	at	01:45 PM
Solar Irradiance (Watts/m ²)	1083	@	26.62 kW	June 02, 1999	at	01:45 PM
Solar Panel Temperature (°F)	99.4	@	21.99 kW	June 14, 1999	at	02:15 PM
Ambient Temperature (°F)	70.7	@	10.17 kW	June 30, 1999	at	08:45 AM
Wind Speed (m/s)	4.617	@	21.33 kW	June 11, 1999	at	03:00 PM

Data Summary

Total Monthly Energy Produced	4,895.1	kWh
Average Daily Energy Produced	163.2	kWh
Cumulative (since monitoring start date)	14,975.9	kWh
Average System Efficiency	4.16	%
Average Capacity Factor	21.93	%
Average Availability	55.49	%

Attached Charts

- Daily Energy Production
- Peak Output Power and Solar Irradiance
- Output Power vs. Solar Irradiance Linear Regression
- System Efficiency vs. Output Power
- Output Power vs. Solar Panel Temperature
- Capacity Factor and Availability

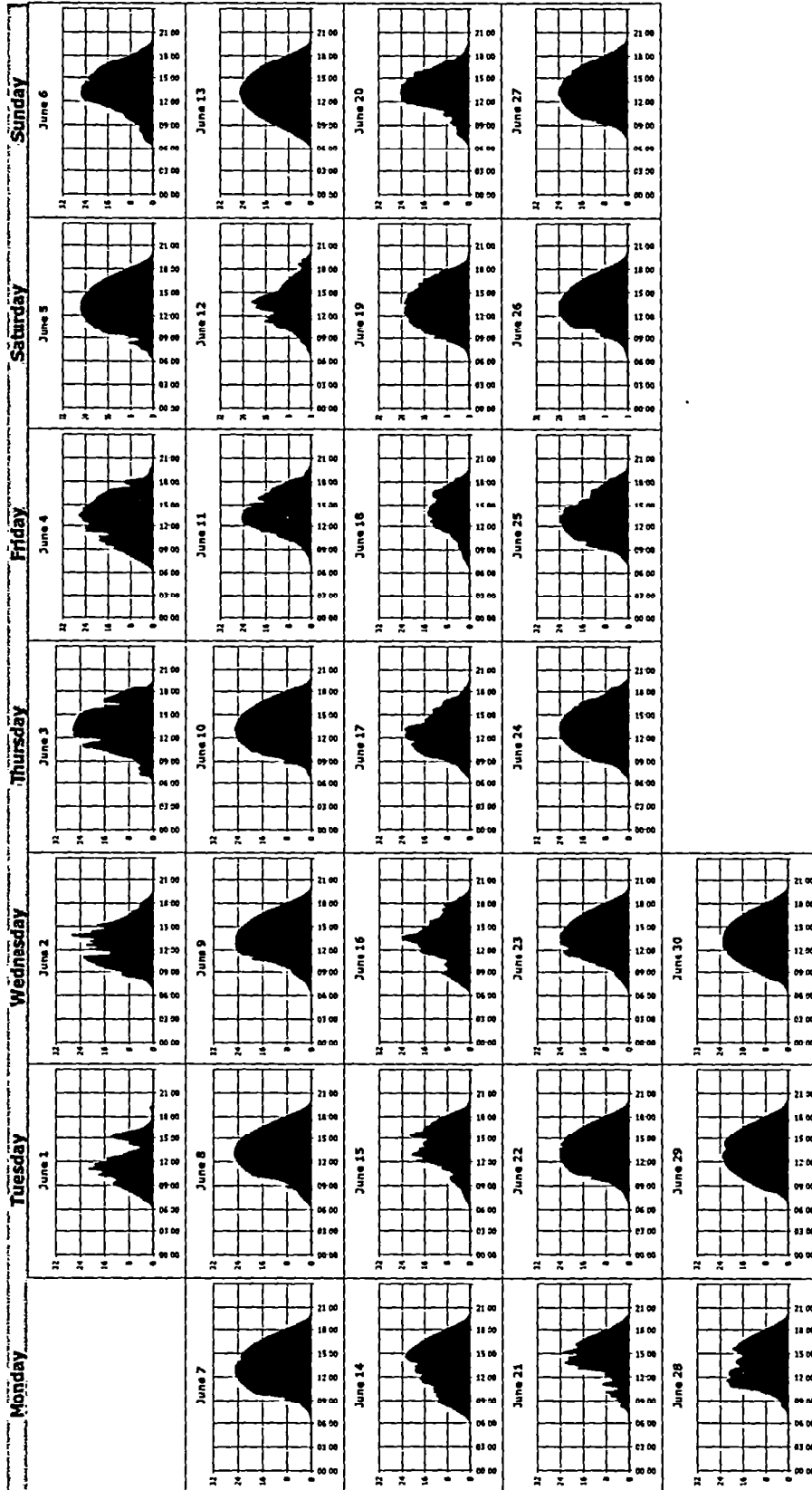
Error List

Date	Description	Resolution
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June 1999

Daily Output Power Profiles

Santa Monica Civic Auditorium PV Data Analysis



June 1999 Summary Report

System Information

Site: Santa Monica Pier
Location: Santa Monica, California
System: 30.81 kW (PTC Rated), 3-Ø, 120/208 VAC, 4 WY
Monitoring
Start Date: September 1, 1998

DAS Uptime

Days of Reliable Data: 30 of 30 100.00%

Peak Parameters

Output Power (kW)	30.0	@ 986 W/m ²	June 03, 1999 at 12:15 PM
Solar Irradiance (Watts/m ²)	986	@ 29.95 kW	June 03, 1999 at 12:15 PM
Solar Panel Temperature (°F)	96.7	@ 23.44 kW	June 14, 1999 at 02:45 PM
Ambient Temperature (°F)	69.8	@ 15.35 kW	June 30, 1999 at 09:00 AM
Wind Speed (m/s)	4.773	@ 0 kW	June 02, 1999 at 01:00 AM

Data Summary

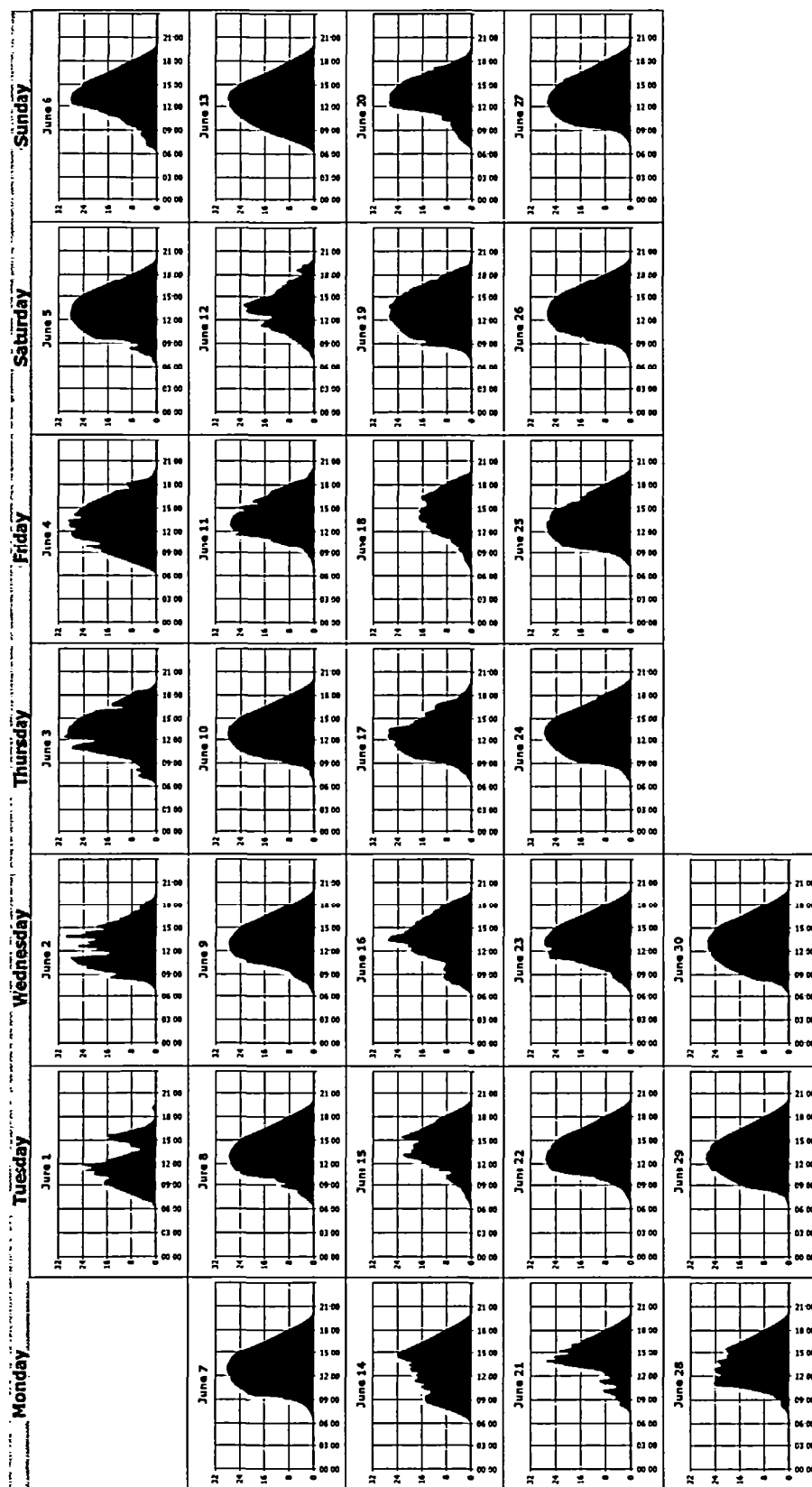
Total Monthly Energy Produced	5,436.0	kWh
Average Daily Energy Produced	181.2	kWh
Cumulative (since monitoring start date)	49,744.0	kWh
Average System Efficiency	9.41	%
Average Capacity Factor	24.51	%
Average Availability	88.65	%

Attached Charts

- Daily Energy Production
- Peak Output Power and Solar Irradiance
- Output Power vs. Solar Irradiance Linear Regression
- System Efficiency vs. Output Power
- Output Power vs. Solar Panel Temperature
- Capacity Factor and Availability

Notes

High availability due to trace amounts of power produced throughout evenings (between 20 to 60 watts); may be attributed to outdoor lighting



Summary Report Period: June 1,1999 to June 30,1999

System Information

Site: University of California, Irvine
 Location: Irvine, CA
 System: 4.9 kW (PTC Rated), 1-Ø, 120 VAC
 Monitoring
 Start Date: November 1, 1997

DAS Uptime

Days of Reliable Data: 30 of 30 100.00%

Peak Parameters

Output Power (kW)	5.13	@ 1190 W/m ²	June 04, 1999 at 11:30 AM
Solar Irradiance (Watts/m ²)	1190	@ 5.128 kW	June 04, 1999 at 11:30 AM
Solar Panel Temperature (°F)	118.6	@ 4.518 kW	June 14, 1999 at 11:45 AM
Ambient Temperature (°F)	92.6	@ 4.518 kW	June 14, 1999 at 11:45 AM

Data Summary

Total Monthly Energy Produced	998.4	kWh
Average Daily Energy Produced	33.3	kWh
Cumulative (since monitoring start date)	12,643.0	kWh
Average System Efficiency	5.47	%
Average Capacity Factor	28.30	%
Average Availability	53.85	%

Attached Charts

- Daily Energy Production
- Peak Output Power and Solar Irradiance
- Output Power vs. Solar Irradiance Linear Regression
- System Efficiency vs. Output Power
- Output Power vs. Solar Panel Temperature
- Capacity Factor and Availability

Error List

Date	Description	Resolution
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